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OF

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VOL. XI, Pt. 1.

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THOMAS OLDHAM, LL.D.,

Fellow of the Royal and Geological Societies of London; Member of the Royal Irish Academy; Hon. Mem. of the Leop-Carol. Academy of Natural Sciences; of the Isis, Dresden; of the Roy. Geol. Soc. of Cornwall; of the Soc. Imp. de Natur. Moskow; Corr. Mem. of Zool. Soc., Lond., &c., &c.

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On the Geology of the DÁRJÍLING DISTRICT *and the* WESTERN DUÁRS, *by* F. R. MALLET, F.G.S., *Geological Survey of India.*

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GEOLOGICAL SURVEY OF INDIA.

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Chapter I.—General description of area and rocks.

For many years the existence of coal has been rumoured from time to time in the outer range of the Sikkim Himalayas. Fragments of the mineral had frequently been observed in the hill streams, and its occurrence in larger quantity had also been reported. Amongst other places, the Sivok valley, close to the debouchure of the Tísta,* was mentioned, and so long ago as 1853 this locality was brought to Dr. Oldham's notice by Dr. Campbell, then Superintendent of Dárjíling. Specimens of the coal were also sent by him to Mr. Piddington, whose analyses of them gave very favorable results.† A brief examination of the Sivok

* The spelling in this report is on the official system, and differs from that on the maps appended, which have been photozincographed from the Revenue Survey maps of the Dárjíling and Jalpigori districts, after the addition of the geological lines.

† Journal, Asiatic Society, Bengal, Vol. XXII, p. 313, & Vol. XXIII, pp. 381, 403.

and neighbouring streams, however, by Dr. Oldham, sufficed to prove that the coal was nothing more than the fossilized stems of individual trees, such as has frequently been observed elsewhere in the same Tertiary rocks, along the base of the Himalaya, and which were economically worthless.*

To Dr. Hooker we owe the first notice of the possible existence of the true Indian coal-measures in this region. In March 1849,† when stopping at Pankabári on his way to Dárjíling, he observed in one of the streams there "carbonaceous shales, with obscure impressions of fern leaves, of *Trizygia* and *Vertebraria;* both fossils characteristic of the Burdwan coal-fields, but too imperfect to justify any conclusion as to the relation between these formations. Ascending the stream, these shales are seen *in situ*, overlain by the metamorphic clay-slate of the mountains, and dipping inward (northwards) like them. ... The carbonaceous beds dip north 60° and 70°, and run east and west; much quartz rock is intercalated with them, and soft white and pink micaceous sandstones. The coal seams are few in number, six to twelve inches thick, very confused and distorted, and full of elliptic nodules, or spheroids of quartzy slate, covered with concentric scaly layers of coal: they overlie the sandstones mentioned above. These scanty notices of superposition being collected in a country clothed with the densest tropical forest, where a geologist pursues his fatiguing investigations under disadvantages that can hardly be realized in England, will, I fear, long remain unconfirmed."‡

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* Journal, Asiatic Society, Bengal, Vol. XXIII, p. 201.

† Himalayan Journals, Vol. I, p. 402. These were not published till 1854.

‡ The following list includes all the other geological papers, &c., on the Sikkim and Bhután Himalayas with which I am acquainted:—

1848.—A few observations on the probable results of a scientific research after metalliferous deposits in the Sub-Himalayan range around Dárjíling. By R. H. Irvine, Esq., M. D.—Journal, Asiatic Society, Bengal, Vol. XVII, p. 137.

The importance of the coal-supply for the great trunk railways of India, has hitherto rendered the examination of the fields south of the Ganges more pressing, from an economic point of view, than the exploration of an out-of-the-way corner of India like Dárjíling. The connection of Calcutta with the hills by the Northern Bengal State Railway, has recently, however, given the question of the existence of coal in the Sikkim mountains a new importance. Copper mines have been

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1850.—Examination and analysis of an orange-yellow earth brought from the Sikkim Territory by Dr. Campbell, Dárjíling, and said to be used there as a cure for goitre. By Henry Piddington, Esq.—Ibid, Vol. XIX, p. 143.

1852.—Notice of graphite sent by Captain Sherwill from Karsiáng. By H. Piddington, Esq.—Ibid, Vol. XXI, p. 538.

1853.—Notes upon a tour in the Sikkim Himalaya mountains, undertaken for the purpose of ascertaining the geological formation of Kánchinjinga and of the perpetually snow-covered peaks in its vicinity. By Captain Walter Stanhope Sherwill, Revenue Surveyor.—Ibid, Vol. XXII, pp. 540, 611.

1854.—Correspondence respecting the discovery of copper ore at Pushak, near Dárjíling. Dr. A. Campbell and H. Piddington, Esq.—Ibid, Vol. XXIII, p. 206.

1854.—Examination and analysis of Dr. Campbell's specimens of copper ore obtained in the neighbourhood of Dárjíling. By H. Piddington, Esq.—Ibid, Vol. XXIII, p. 477.

1855.—Correspondence respecting Dárjíling copper ore. Dr. A. Campbell.—Ibid, Vol. XXIV, p. 706.

1856.—Geological observations in Sikkim. H. Schlagintweit, Esq.—Ibid, Vol. XXV, p. 22.

1861.—Description of a native copper mine and smelting works in the Mahanaddi Valley, Sikkim Himalaya. Communicated by H. F. Blanford, Esq.—Percy's Metallurgy, Vol. I, p. 388.

1862.—Journal of a trip undertaken to explore the glaciers of the Kanchunjinga group in the Sikkim Himalaya in November 1861. By Major J. L. Sherwill, Revenue Surveyor.—Journal, Asiatic Society, Bengal, Vol. XXXI, p. 457.

1865.—Notes on the sandstone formation, &c., near Baxa Fort, Bhután Duárs. By Captain H. H. Godwin-Austen, F. R. G. S., Surveyor, Topographical Survey.—Ibid, Vol. XXXIV, pt. 2, p. 106.

1868.—Notes on geological features of the country near foot of hills in the Western Bhután Duárs. By Captain H. H. Godwin-Austen, F. R. G. S., &c.—Ibid, Vol. XXXVII, pt. 2, p. 117.

worked for a long time past in the same region, but little has been known as to their value; and while lime has been in great demand of late for the railway works, the supply has been scanty and the cost extremely high. It having therefore been decided that an examination into the mineral resources of the Dárjíling district and the Western Duárs should be made, I was deputed to the duty at the commencement of last cold weather.

My attention was of course mainly directed to such points as bear more directly on economic questions, and my observations on some other portions of the geology were necessarily rather scanty. The area which I examined most closely is a band a few miles wide along the foot of the hills, between the Mechi and Jaldoka rivers; that in which the coal-bearing rocks occur. I left the hills to the north of this for the close of the season, and had only time to traverse them rapidly on my way to the different mines. Except at Baxa, the foot of the hills forms the British frontier all along the Western Duárs, and my observations here refer to a mere fringe of the hills immediately north of this line—all that has been topographically mapped, and that my instructions, as well as the time at my disposal, allowed me to survey.

Boundaries of Dárjíling hill territory.

The Dárjíling hill territory (including in this term the Dáling sub-division) is not marked either orographically or geologically as a region distinct in itself. It comprises an area which, as a portion of the great Himalayan range, is quite insignificant, and the limits of which have been determined by political considerations. While the Terai stretches along the base of the hills, our territory is divided from Nepál on the west by the continuation of the Singalela ridge and the Mechi river. Previous to the Bhután war the Tísta formed the eastern limit, but the annexation of the Dáling sub-division from that state has extended the frontier to the river Jaldoka. The Tísta, with its tributaries the Rang Chu and Great Rangít, and the Rammán, an affluent of the latter, form the northern limit of Dárjíling and divide it from independent Sikkim.

Dárjíling hill territory belongs to zone of Lower Himalayas.

The Himalayan range has been commonly divided into three orographical zones:—the great range of snowy peaks, which, roughly speaking, form the axis of the chain; the Lower or Outer Himalaya, forming a broad belt of mountains of inferior, but still considerable, altitude south of the snows; and thirdly, the comparatively low hills forming the Sub-Himalayan zone, either as ridges and spurs contiguous with the outer hills or separated from them by 'duns' (flat-bottomed longitudinal valleys), of which latter the Siválik hills in the North-West Provinces are the type.* These detached ridges are unrepresented along this portion of the Eastern Himalayas, where the Sub-Himalayan zone is locally even wanting altogether.

The basin of the Tísta within the hills approximates to an oblong in form, with the longer axis north and south. Near the north-western and north-eastern corners tower the giant peaks of Kánchínjinga (28,156 ft.) and Dánkia (23,189 ft.) at a distance from each other of rather less than fifty miles, and respectively about sixty and seventy miles from the plains. From Kánchinjinga the Singalela ridge runs southwards, dividing Nepál and the valley of the Támbar from Sikkim and that of the Great Rangít. It is the continuation of this ridge in a south and then south-easterly direction, by Tánglu, Senchal, and Sitáng, with its various lateral spurs, which constitutes the Dárjíling hill territory west of the Tísta. From Dánkia a lofty ridge runs southward by the Gnáream and Chola peaks, separating the basins of the Tísta and the Tursa from each other. At Gipmochi (11,518 ft.) this ridge divides into two great spurs; one running to the south-east and the other to the south-west, including between them the valley of the Jaldoka. It is the lower half of the south-western spur, with its ramifications, that constitutes the hills of the Dáling Sub-division. The hills between the Jaldoka and the

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* Vol. III, pt. 2, p. 5.

Tursa belong to the south-eastern spur, while those between the Tursa and the Raidak form the termination of a great ridge running southward from Chumalári (23,944 ft.) and dividing the basins of those rivers from each other.

At Phallut, near the head of the Rammán river, where the boundaries of Nepál, Sikkim, and Dárjíling meet, the Singalela ridge has an elevation of 12,042 feet, this being the culminating point of the district. The highest eminences are nearly all situated along the continuation of the main ridge, like Tánglu (10,080), Senchal (8,606), and Maháldarám (6,000). Similarly, the highest point of the Dáling hills is where the main ridge first enters British territory, where it has an altitude of over 10,000 feet; the other principal elevations do not exceed 7,000 or 8,000.

The densely luxuriant vegetation by which these mountains are covered, ranging from the matted cane-brakes of the Terai, and the Indian rubber trees and other tropical forms of the deep valleys, to the oak and pine forests which clothe the highest ridges, has been described by Dr. Hooker in his journals. He attributes the heavy rainfall to which such luxuriance is largely due to the fact that the alluvial plain between Sikkim and the mouths of the Ganges is almost a dead level, the foot of the hills being only 300 feet above the sea. Hence the vapour-laden southerly winds from the Bay of Bengal reach the outer range of hills without impediment, while the same current, when deflected easterly to Bhután or westerly to Nepál and the north-west Himalayas, is intercepted and drained of much moisture by the Khásia and Gárro hills in the former case, and the hills of Rájmahál and Chutia Nágpur in the latter. Sikkim is hence the dampest region of the whole Himalaya. *

Drainage.

The valleys on the south-western side of the Singalela ridge are drained by the Mechi, the Bálasan, and the Mahanaddi, the last of which, after receiving the other

* Himalayan Journals, Vol. II, p. 388.

two in the plains, joins the Ganges above Rámpur Bolia. All the remainder of the Dárjíling hills is drained by the Tísta and its tributaries, except the extreme eastern end, where the superfluous water is carried off by the Jaldoka. These rivers eventually reach the Bráhmaputra south-east and east of Rangpur. Thus the Singalela ridge forms at the present time the watershed between the Ganges and the Bráhmaputra. The Mahanaddi and the Tísta flow into the plains in the debatable ground where, under sub-deltaic conditions, a constant struggle is going on between the Ganges and the Bráhmaputra, as they approach each other from the west and from the east, across the great plains to the south of the mountain range. Early in this century the Tísta was tributary to the Ganges.

Lakes.

Here, as elsewhere in the outer Himalayas, lakes are very uncommon and of insignificant dimensions. There is one such about six miles south-west of Hope Town, and another, called Rom Tál, on the Rámthi naddi, some miles east of the Tísta. The latter presents some features of interest. As measured on the map, it is 550 yards long and about 200 broad. For 30 or 40 yards from each bank in the upper part of the lake, dead stumps of trees (which are evidently *in situ*, and not large branches of sunken drift wood), appear above the surface of the water, indicating that the lake, if not formed, has at least increased considerably in depth, within the time that such timber can remain under and above water without falling to pieces. Charred piles below water are known to be capable of resisting decay for centuries, but trees in the above condition would no doubt rot much sooner. Towards the lower end vertical precipices rise from the lake, and here the water seems to be much deeper; too deep to allow of any stumps appearing above the surface. For more than a quarter of a mile above the lake there is a delta of slate shingle, which yearly encroaches on and diminishes the area of the water. The Lepchas have a tradition that three or four generations ago the whole of this

delta formed a part of the lake, and from what I have seen of the transporting power of the hill streams, I can well believe that the present delta could have been formed in this time, especially as the upper Rámthi flows entirely through brittle, easily broken up, slates. The first lateral torrent above the lake on the west side contributes an immense amount of débris from a naked precipice at its source. Of course the commencement of the delta must have been synchronous with the earliest existence of the lake, and although the Lepchas' account may not be strictly true, the delta is certainly not of high antiquity.

As for the mode of formation of this sheet of water, its recent origin puts glacial action in any form out of count, even if the low altitude, about 1,000 feet above the sea, does not do so. The stream for a mile below the exit has a much greater fall (400 feet) than either further down, or above, the lake; and the bed is there filled with huge blocks of Tertiary sandstone, amongst and under which the water flows. I have nowhere, except here and below the Dohír Tál,—a similar but much smaller lakelet, about half a mile to the eastward,—seen an accumulation of this kind; and it seems most probable that both lakes and blocks are due to one or more landslips from the hills above, which have dammed up the original bed of the stream. The blocks are all of Tertiary sandstone, and hence cannot have been washed down stream, as the rocks above the lake are Damúdas and slates. For the same reason, besides those given above, they cannot be the remains of a moraine.

Hot springs.

Hot springs are known to exist in Independent Sikkim, but the only indication of such in the Dárjíling district that I could hear of, was at the Mangphu copper mines on the Tísta. About 600 feet above the river there are two or three small clefts in the slate, the air in which feels warm and moist to the hand when inserted, and 'clouds' are said to issue from them morning and evening, when no doubt the vapour is condensed by the coldness of the air. The clefts are incrusted here and there with sulphate of copper

derived from the decomposition, by the moist air, of the specks of ore in the cupriferous slates. There is probably a warm spring here, the water of which trickles away through the crevices of the rock and the loose débris, without reaching the actual surface of the ground. The geographical co-ordinates are latitude 26° 58′, longitude 88° 29′ (= 88° 25½′ according to Admiralty value), elevation above the sea about 1,300 feet.

Chalybeate springs.

The 'mineral spring' about three miles east of Dárjíling is well known, and was formerly utilized for medicinal purposes, a convalescent depôt having been built near it for the convenience of the troops stationed at Jallapahár. The water, however, is not used at present, and the depôt has gone to ruin. It was also used by the hill-men for rheumatism and cutaneous diseases, the patient being placed in a rude bath made of plantain stems, the water in which had previously been heated by throwing hot stones into it; it was also taken internally. The spring rises amongst the boulders in the bed of a lateral feeder of the Rangnu, which is dry above this point (4th May), and the water, issuing at 62° F., trickles away in a little rivulet, which deposits ochre in small quantity, but has no appreciable taste or smell. It is said to have formerly had a sulphureous odour, when used for medicinal purposes: latitude 27° 2½′, longitude 88° 22′ (= 88° 18½′ according to Admiralty value), elevation 2,050 feet. This is most probably No. 23 of Schlagintweit's list of hot springs,* the temperature of which is 'unknown,' and geographical co-ordinates latitude 27° 3′, longitude 88° 15′, elevation about 1,900 feet. No *hot* spring is known in this vicinity.

Ochre-depositing springs also issue from the black pyritous slates associated with dolomite, east of Baxa, one of which at least has been used for medicinal baths by the natives in the same way as that at Dárjíling.

* Journal, Asiatic Society, Bengal, Vol. XXXIII, p. 49.

General stratigraphy of formations.

If a section be drawn from south to north, from the Terai to the Rammán river, through Karsiáng and Dárjíling, (*vide* Map I), it will be found that the entire succession of rocks has *primá facie* the appearance of a great synclinal. In the southern part of the section, all the strata are inclined towards the north at rather high angles. Towards the centre, the dips are rolling and irregular, while between Dárjíling and the Rammán they are southerly. It is scarcely necessary to say, however, that this appearance is deceptive as far as the Tertiary rocks are concerned; their northerly dip is a constant feature along the Himalayas as far as they have been examined, and it has been usually assumed that they are faulted against the older rocks. It is more probable, however, as pointed out by Mr. H. B. Medlicott with respect to this formation as developed between the Ganges and Rávi,* that the present boundary marks an original limit of deposition against the older rocks, which has been subsequently modified by crushing and local faulting of the strata.

North of the soft massive sandstones and clunch beds which make up the Tertiaries, we come on a narrow band of Damúdas in a more or less altered condition, and including various alternations of sandstone or quartzite, shales, slates, and beds of friable anthracitic coal. Overlying these, without apparent unconformity, are some thousand feet of slates, mostly of grey and green tints, and including here and there a band of quartzite. As we ascend the hills these slates are found to pass, more or less gradually, through mica-schist into gneiss. That the gneiss should be the oldest rock, and either inverted on to the slates, and they in their turn on to the Damúdas, or else that the boundaries should be faulted ones, or finally that the relations of these formations to each other should resemble those of the Tertiaries to the Damúdas, as indicated above, is what will naturally suggest itself. Strange as it may appear,

* Vol. III, pt. 2.

however, that such thoroughly metamorphic strata should normally overlie those in a less altered condition, the evidence points to this conclusion.

From Karsiáng to Dárjíling the gneiss is continuous, verging in some places towards mica-schist. The Dárjíling gneiss generally, in fact, has a great tendency to graduate into the latter lithological type. The dips are uncertain and irregular, with several local anti- and syn-clinals, but on the whole, are northerly near Karsiáng and southerly near Dárjíling. As we descend the spurs towards the Rammán, the slates are found again underlying towards the gneiss, but, in places at least, the boundary between the two series is a faulted one. The fault may be continuous, but I believe that the throw is not very great, and that it has merely complicated a line of junction along which the slates underlie the more metamorphic strata.

If we followed the ill-marked, and often indefinite, boundary between the slates and gneiss, down the valley of the Tísta, and thence back to Karsiáng and on to the Mechi, we find that the underlie of the former is a constant feature. The same thing occurs east of the Tísta also. From the Jaldoka, by Dáling, round to Damsáng, wherever I crossed from one series to the other, the inclination is towards the gneiss. The Pre-tertiary rocks on both sides of the Tísta, may be regarded as belonging to one rather shallow synclinal (including within itself many minor folds), the axis of which is somewhat raised near the river by a secondary anticlinal at right angles to the synclinal. The lower rocks are in consequence of this elevation brought to the surface, and are more fully exposed than they otherwise would be, on account of being cut through by the deep transverse valley of the Tísta. The elevation is not sufficient to bring the Damúdas to the surface along the valley, and these rocks are consequently only exposed along the southern edge of the synclinal, where they outcrop in a narrow band varying from 200 or 300 yards to about a mile in width, and extending from

Pankabári nearly as far as Dálingkot. Here some faulting, combined with a change of strike, cuts them out, and the slates reach to the foot of the hills for several miles, but in the Mo-chu the Damúdas are found again in their old position. Some beds occur near Baxa bearing a resemblance to the same formation, but the neighbourhood of Dálingkot is the most easterly point at which indubitable Damúdas have been observed. Whether the coal-bearing series outcrops anywhere in Independent Sikkim is a question yet awaiting determination.

There is a very large development in the Duárs of variegated slates, which differ considerably in lithological characters from those of the Dárjíling district, and which, besides containing thick bands of quartzite, &c., include a band of dolomite not less than 1,500 or 2,000 feet thick. How far these two groups of slates may be distinct from each other is uncertain, but there are sufficiently strongly marked points of difference to justify one in separating them, at least provisionally. I have accordingly applied the name of 'Baxa' to one series, which is largely developed in the neighbourhood of that cantonment, and 'Dáling' to the other, as it is well seen in the neighbourhood of the old Bhutánese fortress.

The Tertiaries in the Dárjíling district, as along the Himalayas generally, occur as a narrow band fringing the base of the hills. The existence of gaps in this fringe near Dáling and west of the Tursa river is a most unusual phenomenon; in fact, these are the only instances as yet known in which the continuity of the Tertiary band is broken, from the Brahmaputra to the Indus.*

Orography as influenced by stratigraphy.

The alternating quartzites, dolomite, and slates of the Baxa series have had a marked influence in determining the erosion of the hill ranges in the Duárs, where the two first rise into elevated ridges. In the Dárjíling district these rocks are absent; there, while the several formations as wholes differ consider-

* *Vide* Vol. IV, p. 436.

ably from each other in hardness, the rocks composing any one formation are tolerably uniform in this respect. The gneiss is as a whole considerably harder than the slates, and the latter than the Tertiaries; but, excepting some not very important bands of quartzite in the slates, there is nowhere, on a sufficiently large scale to materially affect the orography, any alternation of strata of widely different hardness in the same formation. Hence, in as far as the orography has been influenced by the geological succession of rocks, it has been mainly so by the succession of formations or series, not of minor sub-divisions. It will be seen from the map that the lower Tísta valley has been excavated through the slates, the river, south of its junction with the great Rangít, having selected for its course the axis of the transverse anticlinal alluded to above (p. 11). It seems not improbable that the Tísta between the Rang-chu and the Rangít, and the last-named river below Gok, also flow along anticlinal axes, but the country to the north has not been examined.

The gradation in hardness of the several formations as we ascend from the plains has also had a prominent influence on the elevation of the outer hills. If a view be obtained of these looking east or west, or parallel to the direction of the range, say from Pankabári bangalo across the Bálasan to the hills between that stream and the Mechi, it will generally be found that those composed of Tertiaries seldom rise more than two thousand, and often not more than a few hundred feet. From the junction of the older rocks with the newer, the hills rise more quickly to the outer limit of the gneiss, from which they, often spring rapidly to a total elevation of several thousand feet. Where the Tertiaries are absent between the Jaldoka and Lángti rivers, and the gneiss comes closer than usual to the base of the hills, the latter, rise at once to this altitude.

Chapter II.—Damúda Series.

Typical Damúdas of Ráníganj.

For an account of the Damúdas as typically developed in their unaltered and comparatively undisturbed condition, as they occur in the Damúda valley for instance, I must refer to the various papers already published in these Memoirs. Mr. W. T. Blanford, in his report on the Ráníganj field, the largest and most important of these basins, and that in which the character of the rocks were first established, gives the following summary of the minor groups into which the Damúdas are divisible:—*

Damúda Series.			Thickness in feet.
Ráníganj Group ...	Coarse and fine sandstones, mostly false-bedded and felspathic—shales—coal-seams. The latter frequently continuous over considerable areas.	*Vertebraria; Trizygia; Glossopteris; Pecopteris; Schizoneura; Phyllotheca, &c.*: all plants.	5,000
Ironstone shales ...	Black carbonaceous shales, with numerous bands of clay-ironstone.	Fossils abundant, though not well preserved. *Glossopteris, &c.*	1,400
Lower Damúdas † ...	Coarse conglomerates, with white sandstones, numerous coal-seams of very irregular character, thinning out at short distances.	*Glossopteris; Vertebraria; Zeugophyllites? &c.*	2,000

Dárjíling Damúdas.

The Damúdas in the Eastern Himalayas occur, as already explained, along the southern side of the Dárjíling synclinal, constituting a narrow band between the Dáling slates and the Tertiaries, from Pankabári to near Dálingkot. Like all the other rock-groups, they have undergone great crushing and disturbance, and are tilted up on edge. Although subject to many minor contortions, they dip as a whole towards the north-north-west, generally at high angles, or from 40° to 90°. As might be expected, they have not been subjected to such disturbance without great change in their lithological characters. Frequently the sandstones have been converted into

* Vol. III, p. 31. † Now called Barákars.

quartzites, the shales into splintery slates, and the carbonaceous shales into carbonaceous or even graphitic schists; while the coal has lost a large proportion of its volatile matter, so as to approach to anthracite in composition. Thus while the assays of samples from seventeen seams in the Ránigánj field* show an average composition of carbon 51·09, volatile matter 32·64, ash 16·27, the mean result from five Dárjíling seams gives carbon 70·66, volatile matter 9·20, ash 20·14. At the same time, the crushing to which the seams have been subjected, has squeezed them so that they vary greatly in thickness within a few yards, and has induced a flaky structure in the coal which renders it so friable that it can be crumbled into powder between the fingers with the greatest ease. This flakiness is in fact true cleavage, and the mineral may in one sense be regarded as a 'coal slate.'

The coal seams being the least strongly coherent of the Damúda rocks, faults would be most likely to occur along them when nearly vertical. Hence, perhaps, in some cases the rapid variations in the thicknesses of the seams, and the crushed state of the coal, it having been ground between the two sides of the fault. I cannot bring forward any instances in which faulting can be shown to have acted in this way; it is probable, however, that they exist, although in the great majority of cases, simple crushing without actual dislocation has reduced the seams to their present condition.

The amount of metamorphism in the Damúdas is by no means constant: generally the beds are more or less altered, and not unfrequently highly so, but sometimes there is no alteration whatever, and the rocks closely resemble the typical ones of the Ránigánj field. The coal is an exception, as it everywhere has acquired the above flaky, structure, even when the beds accompanying it have undergone no appreciable change.

The vegetable mould and clay beneath the dense jungle by which the hills are covered, render good outcrops rare, except in the beds of the

* Vol. III, p. 189.

mountain streams, and the only practicable way of obtaining anything like continuous sections is by wading and scrambling up these. The boundaries, as laid down on the map, were obtained by doing so, and connecting the junctions observed in one stream with those visible in the next; hence the band of Damúda rocks seems to have a greater degree of regularity than it probably possesses in reality. An exhaustive survey would probably bring to light cross-faults and other features which have escaped detection.

No Damúdas west of the Bálasan.

No Damúdas are visible between the Méchi and the Bálasan. In the Manjha, the Chenga, and the Dudhia streams the Tertiaries are seen close up to, or near, the slates. The Damúdas seem to have been denuded away before the Tertiary epoch. It is, however, not unlikely that the band is found further west in Nepál.

Damúdas near Pankabári.

In some of the small watercourses between the Bálasan and the road at Kelabári, the Damúdas are just seen at the very base of the hills, with clay slates above them. They are chiefly shaly sandstones, with a seam or two of coal two or three inches thick; in the most westerly of these ravines both rocks dip north 25 west at 80°. No Damúdas are visible in the Bissarbátti stream, but the space they ought to occupy (below the bridge between Kelabári and Pankabári) is blank; and there is but little doubt that they are present there. A three-feet bed of carbonaceous shale, dipping at a low angle to north-west, outcrops in a watercourse just west of Pankabári dák bangalo. It is by no means easy to separate the Damúdas from the Dálings near this, as some of the beds in the coal-series are as good clay slate as any in the Dálings.

A small ravine joins the Bissarbátti stream a little below the bridge above-mentioned. Ascending this, Tertiary sandstones are first met; a short way from the mouth these abut against a two-feet bed of carbonaceous shale, above which is rather indurated quartzo-felspathic

sandstone with a few specks of mica. The quartz is white and the felspathic element buff, giving the rock itself a pale buff color; occasionally there are some thin pebbly layers, the pebbles being of white and red quartz. Besides these beds there are soft shaly micaceous sandstones, with faint vegetable impressions, and dark-grey micaceous shales, in which tolerably well-preserved plant-remains occur, the commonest being *glossopteris.* Four or five carbonaceous beds outcrop in the ravine: firstly, that above mentioned; then one of 18 inches, which includes two layers of coal; this is separated by a few feet from a bed of carbonaceous shale, 3 or 4 feet thick, containing a 9-inch seam of coal. Some distance further up there is a fourth carbonaceous bed, including some strings of coal. The strata in this section dip mostly to north-west at an angle of from 40° to 70°, 60° being about the average.

Rángichang naddi.

The Damúdas in the Rángichang dip mostly towards the north-west at an angle of from 40° to 90°. Some coaly layers are visible, but the best is only 12 inches thick and contorted on a small scale, as well as broken up by closely contiguous slips, of a few feet in throw. The beds, hereabouts, are little altered, but higher up stream they are in their most metamorphic condition, comprising hard quartzites dark-colored slates and graphitic schists. The last is a truly foliated rock, composed of lenticular laminæ of quartz included between the foliæ of impure graphitic matter. It has probably resulted from the alteration of carbonaceous shale, the carbonaceous matter in which has been partially changed to graphite. One of these bands in the Rángichang is 15 or 20 feet thick. Higher still up stream, silvery clay slates come in, which are included with the Dáling rocks.

Rakti naddi.

The Damúdas are well exposed in the Rakti naddi. The contortions of the beds render it difficult to measure the section accurately, but the following is close enough to give a good idea of the general succession of strata. In the lower part of the gorge the stream flows through Tertiary sandstones;

then there is a blank, the next rock visible being hard massive sandstone with little bedding. After another considerable blank we come to—

	Ft.	In.
Carbonaceous shale*	1	0
Sandstone	3	0
Blank	5	0
Brown shale	0	6
Coal	2	6
Sandstone	1	0
Blank	4	0
Brown shale	1	0
Coal (dipping W. 30° S. at 70°)	5	6
Sandstone	4	0
Shale and shaly sandstone	5	0
Carbonaceous shale with some *coaly* layers and sandstone	8	0
Blank	6	0
Carbonaceous shale	4	0
Sandstone	6	0
Coal	0	6
Sandstone	8	0
Carbonaceous shale	1	6
Sandstone	1	0
Coal	1	0
Carbonaceous shale	1	6
Sandstone	10	0
Blank	15	0
Sandstone	1	6
Brown and carbonaceous shales	4	0
Sandstone	2	0
Carbonaceous shale and sandstone	4	0
Sandstone	1	0
Coal (part of thickness concealed by a large block of sandstone), seen	1	4
Sandstone	0	2
Coal	0	5
Blank	4	0
Sandstone with carbonaceous layers (dipping W. 10° N. at 70°)	7	0

* This and the other Damúda sections are given as the strata are met in ascending the streams, and in ascending geological order.

	Ft.	In.
Blank *	300	0
Carbonaceous shale	1	6
Brown shale	1	0
Carbonaceous shale	0	3
Brown and dark-grey shale	3	0
Carbonaceous shale	1	0
Sandstone with some shale	10	0
Blank	100	0
Sandstone	10	0
Brown shale	2	0
Sandstone	1	6
Carbonaceous shale	1	6
Blank	6	0
Sandstone	1	0
Dark grey shale	0	8
Sandstone	0	6
Blank	20	0
Sandstone and carbonaceous shale	8	0
Blank	400	0
Sandstone	6	0
Brown shale	15	0
Sandstone	10	0
Sandstone and carbonaceous shale	2	0
Sandstone	4	0
Carbonaceous shale	2	0
Sandstone	1	0
Blank	200	0
Sandstone	15	0
Coal (varies in thickness from 4" to 16" within a couple of feet, from crushing; dipping N. 10° W. at 60°) ...	0	8
Sandstone	1	6
Dark-grey and brown shale	4	0
Buff and greenish-grey massive sandstone with little bedding; contains some carbonaceous markings ...	100	0
Shale	2	0
Sandstone	20	0
Coal	0	4

* This, and the other large blanks, are the horizontal distances in which rock is obscured, not the thickness of missing strata. There is of course the possibility of good seams of coal being concealed in these positions.

	Ft.	In.
Sandstone (dipping N. 20° W. at 70°)	7	0
Shale and shaly sandstone	21	0
Coal	0	6
Shale and shaly sandstone	7	0
Coal (dipping S. 15° W. at 70°)	1	0
Sandstone	0	10
Brown shale	0	3
Sandstone	3	0
Dark-grey and brown shale	8	0
Shaly sandstone	6	0
Sandstone (dipping N. 15° E. at 80°)	30	0
Alternations of sandstone and dark-grey shale ...	6	0
Sandstone	5	0
Brown shale	4	0
Coal	0	4
Shale; some parts carbonaceous	6	0
Blank	8	0
Hard greenish-grey massive sandstone; but little bedding (dipping N. at 60°)	27	0
Dark-grey shale	6	0
Shaly sandstone	2	6
Dark-grey shale	4	0
Sandstone	0	10
Coal	0	4
Sandstone	2	0
Blank	6	0
Sandstone; some parts shaly	14	0
Coal	0	10
Shale	0	6
Blank	300	0

Then there is perhaps 100 feet of grey slate, and, after a short blank, some hundred feet of similar slate, greatly cut up by jointing. These beds, which I believe form the base of the Dáling rocks, rest on greatly crushed sandstone, with a few crumpled coaly layers. The junction is well marked, but without sensible unconformity.

Chírangkhola naddi.

In the Chochi naddi and in the western branch of the Chírangkhola, sections are obtainable. The beds exposed in the latter are mostly dark-grey micaceous shales, with rather thin-bedded sandstones and some carbonaceous layers.

At the head of the main, or eastern, branch of the Chírangkhola, the Damúdas are well exposed, dipping mostly north-west to north-north-west at 20°—70°, and including buff and grey sandstones, dark-grey and black shales, and several seams of coal, some of which, however, are greatly crushed and disturbed by small, but violent, contortions, which have affected all the seams more or less. The best seam exposed, and adjacent beds, have the following section :—

	Ft.	In.
Dark-grey shale and sandstone, containing abundance of *vertebraria* without other remains—		
Interbanded coal and carbonaceous shale	1	0
Coal with one or two thin partings of carbonaceous shale 5′ 4″ to	7	0
Grey shaly sandstone and dark-grey shale without *vertebraria*.		

The seam dips north-west at 55°, and has a thickness of 5′ 4″, at the level of the stream on the west side; on the east side (20 feet distant) it is 6′ 6″ to 7′ 0″. Here it is traceable for 45 feet up the bank with a nearly constant dip, but far from constant thickness. At 33 feet it is reduced to 2′ 6″, and 12 feet higher (where it seems to be faulted against shaly beds) it is again expanded to 5′ 0″. In the last two spots it is much impurer than below, containing more carbonaceous shale than coal. There is a seam of interbanded black shale and coal lower down the naddi —possibly the same as the above, brought in again by folding, but more probably different—which is 8 feet thick on one side of the stream and only 2 on the other. Another thinner seam is folded sharply back on itself by a small contortion.

Cart road.

The pagdandi (path) south-east of Selim Hill cuts through a 2-feet bed of coal, and a fine section is laid bare along the cart road at the 'Gumpti' below Chunbatti. The rocks are here in their least altered condition, and not much twisted, the dip being tolerably steady throughout the section.

The beds in immediate contact with the Tertiaries are somewhat obscured, and the first recognizable beds are—

	Ft.	In.
Sandstone	5	0
Coal (dipping W. N. W. at 85°, about)	1	0
Sandstone	1	6
Coal	0	2
Sandstone	5	0
Coal, about	1	0
Iron-stained quartzitic sandstone	6	0
Sandstone	3	0
Coal, about	0	6
Sandstone with some coal, much crushed, seen for 20 yards along the road.		
Blank for 20 yards along the road.		
Coal-outcrop with sandstone.		
Sandstone seen at intervals for 70 yards along the road.		
Dark-grey shale,* with one or two carbonaceous layers ...	5	6
Coal	0	9
Dark-grey shale	1	0
Coal (dipping W. 30 N. at 40°)	3	6
Dark-grey shale	0	9
Carbonaceous shale	1	6
Ditto, mixed with dark-grey shale ...	3	0
Coal	0	9
Dark-grey shale	4	0
Sandstone	6	0
Dark-grey shale	8	0
Sandstone	10	0
Dark-grey shale	15	0
Sandstone	1	0
Dark-grey shale	1	0
Coal, about	2	0
Dark-grey shale	3	0
Coal, about	0	9
Sandstone	1	0
Alternations of *coal* and dark-grey shale	5	0
Dark-grey shale	1	0
Carbonaceous shale	0	9

* The dark-grey shales, so common in the Damúdas, are, like those in this section, generally micaceous.

	Ft.	In.
Dark-grey shale	6	0
Thin-bedded sandstone	4	0
Dark-grey shale	10	0
Sandstone (dipping N. N. W. at 30°) about... ...	25	0
Nearly blank for 150 yards along the road; occasional glimpses of shale and sandstone.		
Greenish thick-bedded sandstone...	17	0
Grey shale	0	9
Coal (dipping N. N. W. at 30°)...	0	9
Greenish thick-bedded sandstone...	30	0
There seems to be a fault here.		
Grey shale	3	0
Coal	0	6
Shaly sandstone	2	0
Dark-grey shale	0	6
Sandstone	8	6
Fault here.		
Sandstone	5	0
Dark-grey shale	3	0
Coal (dipping N. N. W. at 30°), 1′ 0″ to 3′ 6″ ...	2	0
Sandstone	5	0
Sandstone, seen at intervals	20	0
Sandstone	25	0
Dark-grey shale	1	0
Coal (dipping N. 30°W. at 50°), 2″ to 14″	0	8
Thick-bedded sandstone	17	0
Dark-grey shale	3	0
Coal (dipping N. 20°W. at 45°)	3	6
Dark-grey shale	1	0
Carbonaceous shale	1	0
Grey shale	3	0
Dark-grey shale	2	0
Coal 2′ 6″ to 3′ 6″	3	0
Sandstone	1	0
Blank for 40 yards along the road.		
Dark-grey shale	2	0
Coal	1	6
Carbonaceous shale	0	3
Coal (dipping N. at 30°)	4	6

This coal is nearly in the strike of the last, and is not improbably the same.

	Ft.	In.
Sandstone	8	0
Blank for 150 yards along the road.		
Sandstone	5	0
Grey shale	2	0
Coal 1' 0" to 2' 6"—may be one of the above beds; it is nearly in the same strike	1	6
Sandstone (dipping N. 15 W. at 35°)	5	0
Grey shale	0	6
Sandstone	0	8
Grey shale	0	5
Sandstone	4	0

Less than 100 yards further on some greenish slate is seen, and a little beyond that some beds of Damúda sandstone, with one or two thin coal seams. Beyond that again the Dáling slates come in finally.

Tindharia ravine.

In the ravine, which runs just south of Mr. Partridge's bangalo at Tindharia, the finest coal seam yet found occurs. In the bed of the stream it dips west 15° north at 80°, and has a thickness of 11 feet, with shale below it and sandstone above. This is one of the seams which I recommended for exploration by horizontal drifts. The latest result shows that at 40 feet in from the outcrop the thickness is reduced to 6 feet; but as such variations are, in the main at least, due to crushing, not to thinning out of the seam, it is very probable that as the drift progresses further the thickness will again increase, and the seam may be found continuous for a long distance, although subject throughout to similar variations.

Lower down stream indications of two or three other outcrops occur. One of these, a couple of hundred yards below the 11-feet seam, was opened out by Mr. Montfort, who found a seam of about 6 feet, dipping west-north-west at a high angle. It is to be remembered in dealing with seams of such uncertain thickness and subject to so much disturbance, in ground where the strata are only exposed at intervals, that several outcrops may in reality only indicate one or two seams.

The paths through Mr. Partridge's tea gardens expose several layers of coal and carbonaceous shale, but I observed none of any considerable thickness.

Síbakhola river.

In the Síbakhola the Damúdas are mostly in a highly altered condition, the sandstone being converted into felspathic quartzite with strings of vein quartz through it, and the shales into dark grey slate breaking into sharp-edged splinters. No good seams of coal are exposed, although there are several thin ones.

Mahánaddi river.

The Mahánaddi also cuts through several thin layers, and one with a minimum thickness of 4 feet; the rest of the outcrop is hidden behind a large boulder. The strata dip mostly to north-north-west at 50°—80°, and are indurated as in the Síbakhola.

Mána river.

The Damúdas are very badly exposed in the Mána, and no good seams of coal are visible.

Kuhi naddi.

Where the central and eastern branches of the Kuhi naddi join, there is a cross-fault which shifts the Damúda-Tertiary boundary to the north on the east side. Ascending the central branch, Damúdas, including several thin carbonaceous layers, are found, dipping towards the north at high angles (60°—90°); a little higher up stream the dip is only 5°, and beyond this on the brow of Látpanchor are Dáling slates, having the same inclination. One of the very few cases of igneous intrusion that I have observed amongst the rocks of the Dárjíling Himalayas occurs in the Damúdas here, which are penetrated by a 7-feet dyke of micaceous greenstone running vertically to east 10° north—west 10° south. The walls of the dyke are sharply defined, and the Damúdas close to it do not show any additional alteration.

Sivok naddi.

The Tertiaries and Dáling beds are seen within two or three hundred yards of each other at the head of the Sivok naddi. The intermediate space is nearly blank, but in one or two spots doubtful Damúda sandstone, dipping nearly vertically, is seen. Even if the whole space be occupied by Damúdas, the band is greatly reduced in breadth here.

Tísta river.

In the Tísta, however, it is again expanded, and attains its maximum breadth of a mile. The strata are considerably contorted. For the last few hundred yards of its course, the Ríyem flows along the crest of an anticlinal, the beds dipping away at either side at angles of 60° — 80.° Ascending the Tísta dips are found to north at 60°, east at 80°, west at 80°, and finally west at 60°, close to the junction with the Dálings. Crushed coal-seams a few inches thick are numerous in both rivers, and at the mouth of the Ríyem there is a bed of coal 3 feet 6 inches thick mixed with carbonaceous shale and sandstone, and dipping north-north-west at 70°. Some of the Damúda sandstones here, as well as in other sections, are more or less calcareous; sufficiently so to give rise to deposits of tufa under favourable circumstances.

Lesu river.

The only rocks seen between the Tertiaries and Dálings in the Lesu are indurated crushed massive sandstone obscurely bedded, the junction of which is not seen with either of the above.

Rumtek naddi.

Near the head of the Rumtek, a small feeder of the Lesu, which it joins from the east side, the stream cuts through an 18-inch coal-seam, dipping north 15° west, at 80°. On the hill side, above a small watercourse, there is a seam of pure coal 7 feet thick, dipping north-north-west at about 20°, and in another ravine close-by the following section is visible. The beds are un-

altered (except the coal, which is as flaky as usual) and remind one of the typical rocks of Ránigani:—

	Ft.	In.
Felspathic sandstone	8	0
Coal (dipping N. 15°, W. at 70°)	2	0
Carbonaceous shale, with a few nodules of ironstone ...	0	9
Clunchy shale	0	9
Shaly sandstone	1	0
Grey arenaceous shale	4	0
Coal	0	1
Felspathic sandstone, with black (carbonaceous) specks through it, and the faces of the beds in the lower part blackened by carbonaceous matter	9	0
Grey shale	0	4
Felspathic sandstone...	1	3
Coal (dipping N. 20, W. at 80°)...	0	3
Carbonaceous shale	1	0
Grey shale	1	6

Blocks of greenstone, evidently derived from one or more dykes, are brought down by the stream.

Rámthi naddi.

But little of the Damúda rocks is seen in the Rámthi, as that portion of its course is mainly occupied by the shingle delta above Rom Tál. In a side jhora an 18-inch seam of coal outcrops with a dip of 50° to west 30° north. At the head of the delta the Damúdas are made up principally of indurated sandstone and dark-grey slates, dipping north-west at 60°.

Ghísh river.

The last Tertiaries seen in the Ghísh are massive sandstones dipping north 30° west, at 30°. Twenty yards higher up stream, one or two coal outcrops are obscurely seen in a little lateral watercourse, and the rainwash brings down pieces of Damúda sandstone and dark-grey micaceous shale containing abundance of *vertebraria*. Beyond this there is some sandstone, dipping west 30° north, at 60°; and just below the mouth of the stream which joins the Ghísh from Songchonlu are dark-grey slaty beds and slaty

sandstone, with carbonaceous partings here and there. A few yards higher up, these give place to light-green (Dáling) slates, no unconformity being apparent.

Lehtí naddi.

Just north of the Tertiary-Damúda boundary in the Lehtí, a thin seam of greatly crushed coal, underlying coarse quartzose sandstone, is visible. About half a mile in a straight line higher up stream, there is a deep gully on the south side of the naddi, in which a very fine section is exposed. The strata are inverted, the Damúdas overlying the Dálings, and both inclining to the south at about 30°; although the dip of the Damúdas is tolerably steady on the large scale, small, but sharp, contortions occur. The strata are here in their most altered condition, the sandstones having been converted into a well-foliated schist, in which the laminæ of quartz are divided from each other by carbonaceous or by chloritic matter, and minute cubes of pyrites are often sprinkled through the rock.

Ranjang naddi.

The Tertiaries appear to be cut off by a fault near the debouchure of the Lehtí, and no remnant of them is found to the eastward for several miles. The Damúdas are met with for some distance along the left bank of the Ranjang, dipping easterly at low angles, and covered, at a varying height above the stream not exceeding 100 feet, by the Dáling slates. They here consist chiefly of coarse quartzose and quartzo-felspathic sandstone, including specks of carbonaceous matter and of silvery mica. There are also some shaly beds, and a few nodules of ironstone, and numerous thin layers of coal, besides one seam of 3 feet 6 inches, dipping north-east at 15°.

Pugo naddi.

The Damúdas are found again in the Pugo naddi, consisting chiefly of crushed sandstones with some shale and thin seams of coal. They dip mostly to north 30° east, at 50°—70°, and are covered on the north-east by the Dáling slates, which on the west are brought against them by a fault.

The change of strike of the Damúdas in the Pugo, to south-east or thereabouts, soon brings the Damúda-Dáling boundary to the edge of the Terai, and for several miles east of the Chel the latter rocks extend to the very foot of the hills.

Mo-chu.

The next point at which I caught the coal-bearing rocks was in the Mo-chu,* at the mouth of the Ruka naddi, where, however, only the highest beds just below the Dálings are exposed, dipping north-east at 60°. They include coarse and fine sandstones, shaly and slaty beds, and two or three coal-seams of a foot thick and less. Lower down stream the older rocks are entirely obscured by recent deposits, and the extension of the Damúdas between the Neora and the Mo is merely conjectural.

Ma-chu.

In the Ma-chu some beds, including carbonaceous layers, are obscurely seen close to, and, unless faulted against, underlying strata which I have referred to the Baxa series. I took these to be Damúda at the time, but as there are some bands of carbonaceous schist included in the Baxa rocks near Baxa itself, the above point, which I shall refer to again, is very doubtful.

No rocks identifiable as Damúdas were met beyond the Jaldoka, and they cannot be considered to have been satisfactorily traced further than the Chel.

Dárjíling Damúdas represent the Ránigani group. (?)

It will be seen from the preceding details that there are no beds in the Dárjíling district corresponding in any degree with the 'ironstone shale' or middle group of the Damúdas in the Ránigani field, and the question arises whether it is feasible to correlate our rocks with the Ránigani or with the Barákar group. It is possible that both are present; as their separation, after the alteration the rocks have undergone, and without the intervening

* Chu is the Tibetan word for river.

and strongly contrasting ironstone shales, would not be easy: it is, however, more likely that only one group is represented. The fossils as yet found in the Dárjíling rocks comprise *Glossopteris* of two species (one of which is *Browniana*, the other undetermined), *Vertebraria*, *Phyllotheca* and *Trizygia (Annularia)*. Of these, all, except the last, are common in both groups as typically developed, whilst *Trizygia* has only been found in the Ránigauj. It is, however, so rare even in these beds, that Mr. Blanford* does not seem to consider its not having been yet found in the Barákars as conclusive evidence of its non-existence there. Further, Dr. Hooker's observation of *Trizygia* in the Dárjíling beds, which he himself speaks of doubtfully, has not been since confirmed. At the same time there is a "plant allied to *Schizoneura*," abundant and generally distributed through the Ránigauj group* of the type field, that has not been as yet observed in the beds in question; but the fossil collections made are too small to allow of satisfactory inferences from this fact.

The lithology of the Dárjíling beds seems to approximate in some respects to that of the Ránigauj group. Mr. Blanford says of the latter, that "the sandstones are generally finer in texture, and are massed in beds of greater thickness, than those below the ironstones; the coarse, white, felspathic sandstone and conglomerates are almost entirely wanting. Nodular hard calcareous bands are frequent; the coal is more regular, of more even quality, and not so frequently a mixture of coal and shale, and the seams have a uniform thickness over considerable areas. Pebbles are scarcely ever seen; shales are common." † In the Dárjíling beds, the sandstones, as a rule, are rather fine-grained; they sometimes occur in thick masses, and coarse, white, felspathic sandstones of the Barákar type are not common; they are not unfrequently somewhat calcareous, and conglomerates are absent. No comparison can be made between the coal-seams in the two localities, owing to the crushed state of

* Vol. III, pt. 1, p. 44.
† Ibid, p. 40.

the Dárjíling beds, and the impossibility of tracing the outcrops for any distance.

It has been found in tracing the Damúdas westward from Ráníganj up the valley of the Damúda, and into Ríwa, that the ironstone shales and Ráníganj groups gradually change in lithological characters. The ironstone shales, as such lithologically, become extinct, and the supposed equivalents of the Ráníganj beds contain no coal. It is quite possible that the series may change its character to the north also. But if it does not do so, and if I am right in correlating the Dárjíling Damúdas with the Ráníganj beds, the lower groups must have been denuded away along the southern face of the Himalayas, after the whole had been tilted up on edge, and before the deposition of the Tertiaries; or more improbably, dropped down by a fault. In either case they would be still present under ground, and may one day or other be found outcropping in some hitherto unexplored part of the mountains. The leading alternative suppositions are, that the Dárjíling Damúdas represent the Barákars, and that the upper groups die out to the north, or else change in lithological character. In the latter case they would be represented in a sub-metamorphosed condition by the lower Dáling beds.

No Damúdas folded up with Dáling beds or gneiss in British territory.

Not often, but still occasionally, one meets with seams of carbonaceous or graphitic schist amongst the Dáling beds; there is a layer of this kind, 2 feet thick, exposed by the Pankabári and Karsiáng road a few hundred yards below Kodabári, and another, some 30 feet thick, on the cart road, a little south of the road location at Karjang.

These, however, are clearly true Dáling beds (and in the above cases near the top of the series) and not Damúdas brought up again to the surface by foldings of the strata on a bold scale. The Damúdas in their most altered condition, as they are seen in the Lehtí naddi for instance (p. 28), have been metamorphosed quite as much as the Dáling beds

generally are; yet the alternations of foliated quartzites, slates, carbonaceous and graphitic schists, and crushed seams of coal, are easily recognizable as Damúdas by any one accustomed to the Dárjíling rocks, and are quite unlike anything met with in the Dálings. The Dáling graphitic schists occur but rarely, and in isolated beds, generally of trifling thickness. They only contain a few per cent. of carbon, and have clearly been formed out of some variety of carbonaceous shale, not out of coal. I have never observed anything like true coal in the upper series.

The same remark applies to the rocks coloured as gneiss, in which I nowhere observed any beds that I had reason to suspect were still-further-altered Damúdas. The secondary folds of the main synclinal (p. 10) are not on a sufficiently grand scale to bring the lower rocks to the surface.

It is not impossible that beyond this synclinal, in Independent Sikkim, where the foldings of the strata are comparatively unknown, outcrops of the Damúda series may yet be found. Neither Hooker nor Sherwill, however, in the journals of their travels in that country, describe any rocks recognizable as such.

Probable existence of Damúdas beneath Gangetic alluvium.

The occurrence of Damúdas in the Dárjíling Himalayas adds a wide expanse to the area within which these rocks are known to have been deposited, at least in patches. It is fairly inferable that such was the case over the country now occupied by the alluvial plains of the Ganges between Rájmahál and the foot of the Dárjíling hills, and extending for an unknown distance to east and west; and it is further probable that there still exist beneath those plains, coal-fields equal, perhaps, in value to those which now supply Bengal with fuel.

The difficulties in the way of finding such are, however, manifest: 1*stly*, the unknown depth of the Gangetic alluvium, which is certainly sufficient to make boring extremely expensive, and may be so great as to render mining impracticable; 2*ndly*, the small proportion of the total

area which, judging from our experience of the known coal-fields, the Damúda rocks might fairly be expected to occupy. There are indeed some reasons, founded on the connection observable in the position of the fields between Ráníganj and the river Koel, with the present lines of drainage, for supposing that the Damúdas were more largely deposited in the main Gangetic valley than in the higher lateral ones.* Probably also the geographical position and geological features of the known coal-fields, would furnish a clue pointing to some portions of the southern part of the plains as more promising than others. At the best, however, the work would be mainly haphazard, and entirely so beyond a limited distance from the edge of the plains. The first borehole *might* strike a field equal to the Ráníganj, and *per contra,* lákhs of rupís might be spent with no return whatever. It may be safely predicted that for many decades no attempt will be made in this direction; but at some future epoch in the History of India, when her manufacturing industries shall have been fully developed, when the demand for coal shall have enormously increased, and the fields of the Damúda valley begun to show signs of exhaustion, it is quite conceivable that the winding engine and the cage will be seen in the midst of the alluvial plains of Bengal, where an unbroken expanse of rice-fields now stretches to the horizon.

CHAPTER III.—*Baxa Series.*

Lithology and stratigraphy.

There is a series of rocks some thousand feet thick, comprising variegated slates, schists, quartzites, and dolomite, which is largely developed in the Western Duárs, but has not been recognized in the Dárjíling territory, except at the extreme eastern end. In the Duárs these strata, like those of the other formations, dip mainly in to the mountain range or more or less truly

* This question is, however, complicated by considerations as to whether the main valley may not have been too deep for the formation of coal-producing beds of vegetable matter, and by the want of knowledge as to how far the rocks have been subsequently denuded.

north, the inclination of the Baxas being generally high; there are of course many minor rolls by which the dip is locally reversed or altered.

The most prominent, and, economically considered, the most important member of the series, is a magnificent band of dolomite which is traceable from the Rehti naddi to the Tursa, and again for some miles east of Baxa. The rocks above and below it being comparatively soft slates, &c., the dolomite rises into a boldly outlined ridge, sometimes as much as 3,000 feet high. The rock is very massive as a rule, with little bedding discernible, but not unfrequently it is shaly, and passes into dark-grey slate. It has a saccharoid structure and light-grey color, but the impure shaly parts are darker; there is an exceptional variety that is finely granular and almost pure white. Nests of more largely crystalline calcite, and little drusy cavities lined by crystals of the same mineral, are often profusely scattered through it. Mr. Tween's analyses of specimens from the Títí naddi, show that it contains about ·60 per cent. carbonate of lime to 38 carbonate of magnesia, and it is probably a normal dolomite (= carbonate of lime 54·35, carbonate of magnesia 45·65), owing its excess of lime to the crystals of calcite which are disseminated through it. These crystals represent the calcareous excess in the original matter from which the rock was formed.

The entire thickness of the Baxa beds is uncertain, as the base of them is nowhere seen. A section is visible on the right side of the Pagli naddi, near the frontier, the lowest strata in which are very brittle, flaggy, silicious beds, with impure calcareous layers interbanded, dipping north-north-east at 30°. These are covered by a few feet of green and white talc schist, and then by slaty, granular quartzite. Beyond is blank for some distance, and then dipping north at 60° are light green and red slates with thin calcareous layers, covered by some hundred feet of white slaty quartzite or quartz schist. Large blocks of the dolomite are brought down stream from the north, showing that that rock is still higher in the series.

A fine section is well exposed in the Títí naddi, which includes (ascending as usual)—

	Feet.
(a).—Green and red slates	500
(b).—Slates with flaggy silicious and calcareous layers ...	800
(c).—White quartzite, including bands of quartz flags and quartz schist	1,000
(d).—Green, black, and red slates, with bands of flaggy quartzite; also of chloritic schist, and flaggy calcareous beds near the top	1,500
(e).—Dolomite, with interbanded layers of dark-grey slate...	1,500
(f).—Dark-grey slates; pyritous and rusty in places ...	300

The thicknesses given are merely eye-estimates: throughout there is a tolerably steady dip between north and north 30° east, at about 60°.

Hauri hill is formed of the main quartzite *(c)*, and that to the north of it of the dolomite. Near Londoin hill the last mentioned rock is thrown to the south-east by a fault, and thence forms a lofty rocky ridge as far as the Tursa, but no trace of the dolomite is visible on the east side of the river. There may be a fault, as suggested by Major Godwin-Austen,* but I am more inclined to think that the dolomite band turns sharply round at the end of the ridge, from south-west—north-east to north—south, and thus disappears below the alluvium.

The rocks on the left side of the river, are green and red slates with layers of quartzite and calcareous flags, &c., and some of dark-grey, slaty rock, in which the surfaces of the beds are blackened by carbonaceous matter. The Bhutánese Súbah of Balla sent a man, who pointed out the locality from which the steatite mentioned by Major Godwin-Austen† came. It was, I was told, obtained loose in the ravine at Balla, but none is found now, and the rock had never been traced *in situ*. It is no

* Journal, Asiatic Society of Bengal, Vol. XXVII, p. 122.

† Journal, Asiatic Society of Bengal, Vol. XXVII, p. 122.

doubt a bed intercalated in the slates, like the talc schist of the Pagli naddi.

Impure, thin-bedded limestone, covered by flaggy quartzite, is exposed at the mouth of the Basra gorge; and in the Alaikuri there are green and dark-grey slates, passing into, and interbanded with, flaggy quartzite. Near the head of the river a thick band of quartzite is crossed twice; whether the same repeated is uncertain. It is coarsely cleaved at a high angle to the bedding. Blocks of a conglomerate, composed of flat rolled pebbles lying parallel to the bedding, mostly of white quartzite in a purple arenaceous matrix, are common in the Alaikuri, as in some other streams to the west, but I did not see the rock *in situ*: it comes, however, from near the head of the gorge. Blocks of gneiss and mica schist form most of the *débris* above the 38th boundary mark, coming down from the Gechijo ridge.

There is a rock sometimes met with (as in the Raimatáng naddi) amongst the impure calcareous beds of the series, which consists of interbanded layers of dolomite, varying in color from dirty white to dark red,* red jasper, and thin seams of micaceous iron, and including besides, irregular seam-like nests of quartz mixed with chlorite. The rock varies from one in which the dolomite and jasper are interbanded in irregular layers of ¼ or ½ inch thick or more, to an impure dolomite merely containing seams and nests of jasper, &c. The alternations show well the sharp foldings on a small scale, which are common in the Baxas. The rock is a subordinate one, and has no connection with the great dolomite band. Large blocks of hornblende rock are also brought down by the Raimatáng.

None of the streams west of Baxa bring down boulders from the dolomite band, which, however, re-appears in full force in the Jángti. The stream flows in this part of its course, through a narrow rocky gorge encumbered with huge blocks of stone fallen from the sides, down which

* The color-giving iron is in the state of peroxide, and hence the rock is a ferruginous dolomite, not a true ankerite.

the lime-charged water trickles over large masses of tufa. The outcrop of the dolomite, as laid down on the map, is half a mile wide; the average dip being about 60°. This indicates a thickness of dolomite (with some interbanded pyritous black slate) of 2,300 feet, if none of the beds are repeated by contortions or faulting. It seems that the dolomite has been shifted to the south by a cross-fault east of Baxa, and after being much denuded, covered up by the Tertiaries, beneath which and the alluvium it probably runs as far as the Tursa. Near the upper end of the Jángti gorge, quartzite dipping at 20° is faulted against the dolomite, whilst it is underlaid by flaggy quartzite at the lower end. Next the latter rock, is some quartzite or quartzitic sandstone, of which the faces of the beds are blackened by carbonaceous matter, and below this the Tertiaries come in.

The dolomite has been traced as far east as Jainti Hill, but not beyond; it is probably either cut off by a fault here, or trends northwards towards Sachaphu Hill.

Just north of the Tertiaries on the left bank of the Raidak, a section is exposed of a steep anticlinal with east-west axis. The beds in the centre, or the lowest, are purplish-red slates, interstratified with reddish quartzite; over these is 60 or 80 feet of quartzite (of which the surfaces of the beds are frequently blackened by carbonaceous matter), with some layers of graphitic schist, or perhaps graphitic quartz-schist would be a more correct term, as the amount of carbon does not exceed 10 per cent. or so. These beds are covered by yellowish shattery quartzite. Between the Raidak and the Chengti black-looking rocks, no doubt the above graphitic schists are exposed high up on the mountain side, in two or three places, by landslips; but I observed no trace of them in the Rhekua naddi, where the first rocks north of the Tertiaries are red slates and quartzites.

Relations to Dáling beds and Damúdas.

The Damúdas and the Dáling series (as far as the area examined is concerned) being almost exclusively confined to the Dárjíling territory, and the Baxa beds to

the Duárs, whilst there is a *terra incognita* between the Jaldoka and the Daina, where the base of the hills retreats several miles beyond the British frontier, sections are almost entirely wanting to show the relations of the Baxa beds to the other series. In ascending the Ma-chu, next to the beds containing carbonaceous layers, mentioned at page 29, are very brittle silicious flags, with pink calcareous layers, and a few of red shale, dipping north-north-west at 50°; these are quite similar to some of the Baxa beds in the Pagli and Tití sections (p. 34). Beyond these, and apparently overlying them, are green slates of the Dáling type. The slates in the Lángti are also Dáling, and these seem to overlie those further south which are Baxa. Such appears to be the normal position of the two series, and it is on the strength of this that I have coloured the area north of Baxa as Dáling. The only place where I actually penetrated sufficiently far into the hills to examine this area, was in the Alaikuri, the slates in the upper part of which are of an undecided type which might belong to either series. Unless, however, there be a fault between the gneiss and the Baxa beds, it is difficult to see how the Dáling series can be wanting.

The main difficulty is, however, with respect to the relations of the Baxas and Damúdas. I cannot think that the strata, including graphitic schists, seen in the Raidak, are Damúdas, as they are interstratified with beds totally different from anything associated with the latter rocks west of the Jaldoka; and, as I have previously shown, such carbonaceous schists occur here and there in the Dáling beds, where they certainly have nothing to do with the coal-bearing series. The Raidak beds contain no coal, dark-grey shale, or other characteristic Damúda rock. It is not easy to see how the Baxas can be younger than the Damúdas; as, in the Dárjíling territory, the latter rocks immediately underlie the Dálings without sensible unconformity. On the other hand, if they be older, where are the Damúdas in the Ma-chu section, unless, indeed, they are dropped down by a fault? Judging from the Dárjíling and Bhután ground alone, I should say the Baxas were the oldest beds of all; but,

on the other hand, one cannot but be struck by some points of resemblance between the latter rocks and those included in Mr. Medlicott's 'Krol group' at the top of his Himalayan series of the north-west.

CHAPTER IV.—*Dáling and Dárjíling* Series.*

Relations of Dáling beds to Damúdas.

Sections are frequently obtainable, showing the junction of the Damúdas and Dáling series. In every case which came under my notice, the two series are sensibly conformable to each other, although generally there is a very marked and sudden lithological change.

Thus, in a deep gully which joins the Lehtí naddi from the south (p. 28) the strata dip to the south at about 30° and are inverted, the Dáling slates being underneath. The last-mentioned rocks, of which three or four hundred feet is included in the section, consist of alternating light green and dark greenish-grey, slightly greasy slate, the latter variety looking black at a little distance. Some of these alternations are 50 or 80 feet thick, others only an inch or two, and they prove that, here at least, the fissile planes coincide with the bedding. Resting on these beds, at a clearly defined horizon, is slaty Damúda sandstone. The thin alternations of variegated slates at the junction do not bring to light the least unconformity; and the Damúdas include one or two thin layers of light green slate, similar to that below, at a few inches from the base. Above this there is some hundred feet of highly altered Damúdas, comprising foliated quartzose schists, thin seams of coal, and beds of carbonaceous schist, &c., whilst carbonaceous matter is completely absent from the slates below.

Sections are obtainable on the southern face of Látpanchor, and in the Ranjang naddi, where the Damúdas dip at 5° and 15°, and in

* The gneiss above the Dáling beds is called 'Sikkim gneiss' on the map, but 'Dárjíling' is a preferable name, as the gneiss of Kánchinjinga in Independent Sikkim may be of a different age.

each case they are covered by Dáling slates dipping at the same angle, but the absolute junction is not visible. In the Pugo, again, the older series consists chiefly of crushed sandstones, with some shale and thin seams of coal. The highest beds are graphitic schists, with thin layers of grey quartzite, dipping north 30° east, at 60°. Immediately covering these, with similar dip, are alternating dark greenish-grey and light green, slightly greasy slates, which may be traced for at least some hundred yards up stream. The junction is perfectly sharp, and the slates do not contain any carbonaceous matter.

In the Mahánaddi, indurated Damúdas of the usual character, with coal seams, &c., are visible for about three quarters of a mile. The last beds, in ascending the stream, are of crushed massive dark-grey sandstone, within 6 feet of which are light green slates dipping at 80° to north-north-west. These continue for over a mile and a half up stream, with a remarkably constant lithological character, until they begin to graduate into mica schist and gneiss. Throughout the entire distance I did not observe a trace of carbonaceous matter.

In some other sections the junction is not so perfectly sharply marked as in the above. In the Tísta, for instance, Damúda sandstone and light green slate are interbanded for some yards, and in the neighbourhood of Pankabári the junction is sometimes difficult to determine. Between Ráni Hát and the cart road, there is a band of slaty conglomerate at the base of the Dálings, of insignificant thickness, which dies out to east and west.

Lithology.

The light green slightly greasy slates, sometimes interbanded with a dark greenish-grey kind, mentioned in some of the above sections, are the most prominent variety of rock for some distance north of the Damúda outcrop. In many places they are thinly fissile, but there is a system of divisional planes (sometimes more than one), generally at an angle of 30° or 40° to the planes of fissility, which causes the slate to break across into small pieces. Not unfrequently the rock contains thin laminæ of white quartz parallel to

the fissile planes, showing that the latter are due to foliation, not to cleavage. These slates pass insensibly into ordinary clay slates, more or less earthy or silvery according to the degree of alteration they have undergone. There are also bands of quartzite and quartz flags, and occasionally some of hornblende schist. The latter are sometimes slightly calcareous, or composed of actinolite with magnesian carbonate of lime between the crystals, and this rock even passes into impure dolomite containing much actinolite. Such beds are, however, very rare and insignificant. The almost complete absence of lime in the Dáling beds is one of the most prominent lithological distinctions between them and the Baxas; another is the rarity of brilliantly-coloured alternations of slate, like those in the Títí naddi section, the colours of the Dáling slates being less variegated and more sombre.

The sections west of the Mahánaddi do not show much of the light green slate, so prominent to the east of that river; along the cart road, for instance, they are more earthy and arenaceous. I am inclined to think that this is merely due to a difference in metamorphism, combined perhaps with lateral change in lithological characters; it may, however, be of more importance, and connected with the disappearance to the east of the slaty conglomerate which forms the base of the Dáling series in the neighbourhood of Selim Hill.

Dáling beds underlie the gneissose.

I have said that the Dáling beds everywhere underlie towards the gneiss. Along the outer face of the hills there is not much difficulty in drawing a line between the two, for although there is always a passage from one rock to the other, this passage is comparatively rapid. But as we ascend the valley of the Tísta towards the interior of the hills, the lower beds become more altered, and frequently changed into mica schist and even gneiss, whilst the gneiss of the upper strata is often of an indefinite character with much mica schist. The rocks colored blue about Kálingpung and Damsáng, and west of the Tísta, frequently include bands which are quite as much, or more, altered than others in the area colored pink.

All that can be done is to divide the less from the more altered strata on the large scale, and it must be remembered that this is merely a provisional separation of convenience, as there is no evidence of any stratigraphical break. The same difficulties were experienced by Mr. H. B. Medlicott in the north-western Himalayas,* by whom at least a portion of the metamorphic rocks were shown to be on the horizon of some groups of his slate and limestone series.

The slates appear to be faulted against the gneiss in the Little Rangít and on the Takvor spur; and the fault may extend to the eastward. I nowhere, however, elsewhere observed any indications of faulting along the junction, nor of pseudo-faulting, from deposition of one series against a steep pre-existing cliff of the older rocks. It is beyond dispute that the Dáling beds do underlie the gneiss, and it is, I consider, equally certain that they do so normally and not from inversion. The latter hypothesis would involve nothing less than the complete inversion of all the pre-tertiary rocks over the greater part, if not the whole, of the Dárjíling district. It would imply in fact that inversion is, so to speak, the normal order of things; for the facts cannot be explained by mere local inversion along the lines of contact. Such superposition of fully metamorphosed rocks on those in a less highly altered condition is a phenomenon by no means confined to the Dárjíling hills. It has been described by Mr. Medlicott † as the usual order of things in the north-western Himalayas, amongst the strata of his Himalayan series, with which, there can be little doubt, the slate and gneiss rocks of Dárjíling correspond more or less completely ‡.

* Vol. III, pt. 2, and Panjáb Gazetteer, article Geology.

† Vol. III, pt. 2, and Panjáb Gazetteer, article Geology.

‡ In this connection I would refer to Mr. R. Mallet's recent paper on volcanic energy (Philosophical Transactions of the Royal Society, vol. 163, page 147), in which the author shows (page 168) that if several horizontal beds or layers of rock, of different compressibilities, be subjected to tangential pressure, the work of compression will be greatest in the layers of least compressibility, and consequently the heat evolved greatest also. If the upper of two layers be the less compressible, it will be the hotter, and we may therefore reasonably conclude, the more highly metamorphosed, if the elevation of temperature be sufficient to induce such action. The extent to which the Himalayan rocks have been subjected to tangential pressure is abundantly shown by their disturbed and folded condition.

The greater portion of the area coloured pink is occupied by true gneiss, but the rock very frequently passes into mica-schist, or into a variety intermediate between the two; a felspathic mica-schist or gneissose schist. Bands of quartzite occur but rarely, and hornblendic rocks are extremely uncommon and in beds of insignificant thickness. The actual gneiss itself is generally composed of translucent, colorless or grey quartz, white opaque felspar, and dark brown and silvery mica; it varies in texture from a fine-grained to a moderately coarse rock, lenticular layers of different degrees of coarseness being commonly interbanded. Almost the only accessory minerals are kyanite, schorl and garnet, the last mentioned of which is sometimes disseminated through the mica-schist in coarse crystals of considerable size. The gneiss is always well foliated, and the layers are not unfrequently wavy, the length of the waves varying from a few inches to as many feet. This is the incipient stage of the sharp crumplings on a small scale, which are also common, by which the layers are folded completely back on each other.

Lithology of gneiss.

I have not observed any granite in the Dárjíling district, but Dr. Hooker describes the gneiss further north, near Kánchinjinga, as penetrated by numerous veins, the intrusive rock being sometimes fine-grained, in other cases largely crystallized and composed of "pearly white prisms of felspar, glassy quartz, and milk-white flat plates of mica, with occasional large crystals of tourmaline."* This gneiss may be different from that of Dárjíling, and correspond with Dr. Stoliczka's 'central gneiss' of the north-western Himalayas, which is penetrated by innumerable granite veins, and which he considers to be the oldest formation of that area and of pre-silurian age.

Absence of granite.

I have shown that the junction of the Dáling beds and the Damúdas is a natural one. It follows from this and the above considerations respecting the superposition

Dáling and Dárjíling series post-Damúda.

* Himalayan Journals, Vol. I, p. 251.

of the Dárjíling gneiss, that both it and the Dáling beds must be younger than the coal-bearing rocks. It would be useless, however, in the present state of our knowledge, to attempt to correlate them with the known post-Damúda rocks south of the Ganges; as, owing to their altered condition, we are without reliable lithological, as well as without fossil, evidence to base our conclusions on.

Dárjíling gneiss distinct from that of Bengal.

It is scarcely necessary to add that the Dárjíling gneiss must be vastly younger than that of Bengal*, which was fully metamorphosed and enormously contorted and denuded before the Damúdas were deposited on it. The Dárjíling gneiss presents several points of difference lithologically. It is more quartzose and the older rock more felspathic; the felspar is, I believe, always white in the Dárjíling rock, while it is very frequently red in the other. Again, the bands of dense tough hornblende rock which are so common in the older formation, are absent in the newer, or only represented by insignificant layers, and, as far as my examination goes, there is no limestone or dolomite in the hill gneiss. The latter, at least in the Dárjíling district, is never granitoid as the Bengal gneiss so frequently is, and it has a greater tendency to pass into, and contains more, mica-schist.

Bengal gneiss.

Proceeding up the left bank of the Raidak river, the first rock met with is hornblende schist in thick beds dipping north 10° west at 50°, and forming a low eminence; only a small thickness is seen. Beyond this is blank for a couple of hundred yards, and then Tertiaries come in, dipping locally to north at 80°. There can hardly be a doubt that this rock belongs to the gneiss which forms most of the hills that are scattered over the alluvial valley of the Brahmaputra, and which, according to Mr. Medlicott, there is no reason to suppose is distinct from that of Bengal. The southerly trend of the Tertiary hills both east and west from the debouchure of the Raidak make it probable that the Tertiaries are not faulted against, but

* The gneiss south of the Ganges is generally spoken of as the 'Bengal gneiss.'

overlie the gneissose rocks. The above outcrop is the one solitary point at which the Assám gneiss has been observed at the foot of the hills between Nepál and the Goalpára district.

Chapter V.—Tertiaries.

Lithology.

The Tertiaries fringe the older rocks continuously from close to the Mechi eastward nearly as far as Dálingkot. They are made up mainly of soft massive sandstones and clunchy beds. The most prominent variety of sandstone is a rather soft, highly felspathic and slightly micaceous, white rock of medium fineness, with black specks; a pepper and salt-coloured rock. There are also light buff-coloured sandstones varying in texture from rather coarse to rather finegrained, and passing into fine earthy beds. Well-rounded pebbles, mostly of white quartz, but sometimes of gneiss and schists, are very commonly scattered through the sandstones. Near the bottom of the series they generally contain merely a stray pebble here and there, but higher up, the pebbles increase in number, and towards the top, layers and bands of conglomeratic sandstones are frequent. The pebbles are generally under 2 or 3 inches diameter and never approach in size to boulders. The sandstones are usually thick and often very massively-bedded, and false-bedding is common. They sometimes contain rounded concretionary masses of clunch which have much the appearance of rolled pieces of foreign rock. The clunchy beds are grey, greenish-grey or greenish, often micaceous and generally somewhat calcareous. Usually the calcareous matter is equally diffused through the rock, but sometimes it is aggregated in nodules resembling potatoes in form and size. In a few instances there are layers of impure light grey limestone mixed up with the clunchy beds. The latter also become bedded in places and pass into grey, slightly calcareous shale. There are also dárk grey shales not unlike unaltered Damúda. The above varieties are generally mixed up in frequent alternations, but

great thicknesses of soft massive sandstone unmixed with other rocks also occur, especially towards the upper part of the group; the clunch and shaly beds are most abundant towards the lower part.

Fossil stems: lignite.

Fossil stems are frequent in the sandstone. They occur up to a foot or so in diameter and 10 or 15 feet long, being generally more or less flattened by pressure. In most of them the original woody part is replaced by carbonaceous sandstone, while the bark is represented by brittle jetty lignite, breaking with conchoidal fracture. In some, however, carbonaceous sandstone and lignite are interbanded with each other throughout the entire thickness of the stem, in very irregular layers parallel to the structure of the wood. Occasionally the stem consists entirely of lignite, and is then generally squeezed quite flat. Besides such recognizable stems, little irregular masses and strings of lignite are often met with in the sandstone, but never of any size, the largest I ever saw containing less than 2 cubic feet.

Coal.

There are, however, a few beds of coal in the Tertiaries; not jetty lignite with conchoidal fracture, but soft and flaky, very much resembling the Damúda coal in outward appearance. The possibility of its being Damúda caught up in the Tertiaries suggested itself to me, but further examination convinced me that it is not so. At least two such beds are met with on the cart road, one of which is a lenticular mass 6 feet thick, but only extending for a few yards laterally; it may represent a local accumulation of drifted vegetable matter. The other varies, where exposed, from 9 to 2 inches in thickness, and what is possibly the same bed is exposed at two or three points lower down the winding road. An assay of the coal from the second bed shows that it contains 43·2 carbon, 19·6 volatile matter, and 37·2 ash, or nearly half as much volatile matter as carbon. The highest percentage of volatile matter in the Damúda coal is less than a fourth that of the carbon, and the average only one-eighth. These Tertiary coal beds are by no means common, not more than half

a dozen outcrops having been observed altogether, none of which showed any reasonable promise of commercial value.

Ferruginous beds.

I shall allude to the ferruginous beds of Lohárgarh when describing the iron ores of the district. I may here, however, point out the similarity in geological position of the Lohárgarh rock, occurring as it does towards the base of the group, with the well-known ores of Káládhúngí and Déh-chaurí below Naini Tál. The latter are found in the clays at the base of the lignite-sandstone, and are represented at intervals along this zone as far as the Nahan group of the north-west has been traced.* The occurrence of the Lohárgarh rock renders it probable that the ferruginous band is represented along the entire length of Nepal also, or from the Satlej to the Mechi.

Thickness.

A fine section of these Tertiary rocks is exposed in the Mahánaddi; where they dip with considerable steadiness towards the north-north-west, or up stream, at angles the mean of which is probably about 35°. The entire length of section is three miles and three quarters, indicating, if all the beds passed over represent true vertical thickness, and excluding possible faults, a total of over 11,000 feet.

Dr. Hooker was therefore in error in supposing that these strata are represented to but a trifling extent in the Dárjíling district, and that they rise to but a few hundred feet above the sea there.† It is true that they do so in the neighbourhood of Pankabári, where they were examined by him, but east of the Mahánaddi many of the Tertiary hills are over 2,000 feet high.

Line of boundary.

The relations of these rocks to the older formations, along the line of junction in our present area, seem to resemble exactly those in the north-western Himalayas which have been described so fully by Mr. Medlicott. He believes "that

* Vol. III, pt. 2, p. 178.

† Himalayan Journals, Vol. I, p. 403.

the junction is primarily a line of original contact, possibly modified by subsequent faulting,"*—that the original limit of deposition of these rocks was a steeply escarped coast line, against which the sands and mud were banked. By subsequent tangential pressure the consolidated strata were crushed up so as to present a pseudo-underlie towards the older formations; whilst the steep original contact gives the junction the appearance of being a faulted one. The direction of such an escarpment as the above, in highly inclined strata, would generally be determined by the strike of the bedding; and in the Dárjíling district, the persistent parallelism of the Tertiary-Damúda and Damúda-Dáling boundaries would seem to indicate that such an escarpment may have been determined by the outcrop of the upturned Damúdas.

Break in the continuity of the Tertiary fringe.

The Tertiaries are wanting for some miles eastward of the Lehtí naddi; they occur again in the Ma-chu, but are again absent for forty miles eastward of the Jaldoka. Their absence along this part of the lower hills was first pointed out by Major Gowdin-Austen; and, as observed by Mr. Medlicott,† it is the only known instance of the kind from the Indus to the Bráma Khund. With respect to the question whether their absence is due to denudation or to their never having been deposited along this portion of the hills, I think the former is decidedly the more probable explanation. The thickness of strata exposed in the Ghísh river is as great as anywhere to the west; the group does not show any sign of diminishing thickness; yet three miles further east it has entirely disappeared. The older formations do certainly stretch further south here, owing mainly to a change of strike, and it is possible that they originally ran still further south as a promontory in the Tertiary basin of deposition. There is, however, no evidence that they did so; and it is more difficult to explain the removal of such a promontory, than it is to explain the removal of the softer Tertiary rocks on the alternative supposition.

* Vol. III, pt. 2, p. 102. † Vol. IV, p. 436.

Recent boulder deposits.

Between the Chel and the Langti there are enormous recent boulder deposits,* which become finer to the south, and eventually graduate into the ordinary alluvium of the plains. They form cliffs of three and four hundred feet high about the debouchures of some of the rivers, like the Jaldoka. Remembering the difficulty frequently expressed by Mr. Medlicott, of separating the true Sivalik strata of the north-western Himalayas from the recent deposits of the Duns, it struck me as possible that some of the deposits in question might represent the Sivalik group. I did not observe anything, however, tending to prove that such is the case, or leading me to make any separation in them. The deposits, which occur all along the base of the hills, may not in reality perhaps be more largely developed here than elsewhere, but they are cut through much more deeply by the rivers; and it is to be noted that this feature occurs in a portion of the strip where the Sub-Himalayan hills and rocks are absent.

Tertiaries near Baxa.

The latter reappear some miles east of the Tursa, and are thence found continuously as far east as the Sankos river, which was the furthest point I reached. At the debouchure of the Raimatáng, there is at the base of the Tertiaries some two or three hundred feet of soft, dark-red, slightly micaceous, earthy sandstone and sandy clays mottled red and light greenish. Above them are soft massive sandstones of the ordinary type. The passage beds are exposed at the debouchure of the Jángti; ascending the stream, we have, dipping at 70° to north—

	Ft.
Soft white sandstone with black specks	40
Sandy clay or clunch; red, mottled with light green ...	30
Grey clunch	2
Light greenish clunch mottled with red	10
Sandstone like the first-mentioned	5

* *Vide* Major Godwin-Austen's paper, Journal, Asiatic Society, Bengal, Vol. XXVII, pt. 2, p. 117.

Then a blank, beyond which the ordinary sandstones, &c., come in. These beds remind us of the mottled red clays, &c., which Mr. Medlicott describes at the base of the Nahan group.

Conglomerate beds are more largely developed in the Baxa Tertiaries than in those of Dárjíling; as usual, they occur near the top of the group. In the ravine below and immediately west of the right picket at Baxa there is a considerable thickness of them—rolled pebbles of sizes up to 6 inches diameter in an arenaceous matrix. Similar bands are found in the Rhekua naddi, which flows into the Sankos.

Tertiaries represent Nahan group.

A comparison of the above lithological characters with those given by Mr. Medlicott for his Nahan group of the north-western Himalayas * shows the strong similarity between that group and these Dárjíling beds. The Nahans are essentially the 'lignite-sandstones' of the North-West; and our rocks further agree in the occurrence of ferruginous beds and of red clays and sandstones near the base, as well as of conglomeratic bands near the top. Mr. Medlicott felt satisfied from his examination of the Tertiaries further east, in Upper Assam, that they there represent the Nahan group; and he further pronounces my specimens from the Dárjíling country to be of a decidedly Nahan type.

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* Vol. III, pt. 2, p. 114.

ECONOMIC GEOLOGY.

CHAPTER VI.—*Coal—Graphite.*

COAL.

Principal known out-crops.

I have mentioned all the coal out-crops as yet found, when describing the Damúdas, but it may be well to give here a list of the more important ones, or excluding those under 2 feet thick. Proceeding from east to west, we have—

		Thickness of coal at out-crop. Ft.	In.	Dip.
Rakti naddi		2	6	70°
Ditto		5	6	70°
Ditto (part of thickness concealed) seen ...		1	4	70°
Chirankhola naddi	5′ 4″ to	7	0	55°
Ditto	2′ 0″ to	8	0	
Pagdandi, south-east of Selim Hill		2	0	
Cart road		3	6	40°
Ditto		2	0	
Ditto	1′ 0″ to	3	6	30°
Ditto		3	6	45°
Ditto	2′ 6″ to	3	6	45°
Ditto		6	0	30°
Ditto		2	6	35°
Tíndharia ravine		11	0	80°
Ditto		6	0	
Maháṇaddi river (part of thickness concealed) seen		4	0	70°
Ríyem naddi		3	6	70°
Rumtek naddi		7	0	20°
Ditto		2	0	70°
Ranjang naddi		3	6	15°

I have spoken of the above as out-crops, not as seams, because the vegetable mould and clay beneath the dense jungle render it impossible to trace the seams for any distance. They are seldom visible except in the very beds of the streams, nor can a seam be recognised in a second out-crop with any certainty on account of its rapid variations in dip and

strike, and still more in thickness. The sections are seldom sufficiently good to trace the seams by means of the associated beds. Thus the same seams almost certainly out-crop more than once on the cart-road, and the 6-feet Tindharia seam may be the same as the 11-feet one.

Rapid variations in thicknesses of seams.

I have included all out-crops of 2 feet and upwards in the list, not on the supposition that a 2-feet seam of coal would pay to work, but, as I have previously explained, the seams vary greatly in thickness within a few yards. Thus, one of those in the Chirankhola is 8 feet on one side of the stream and only 2 on the other, and another on the cart road varies from 1 foot to 3 feet 6 inches in the short distance along which the out-crop is visible. A thickness of 2 feet at the out-crop may be the *minimum* thickness of the seam.

There can be no question that these rapid variations are due mainly, or almost entirely, to the crushing which the rocks have undergone; but to some extent they may be caused by variations in the thickness of the bed as it was originally formed. How much should be attributed to the latter cause is a most important element in the question of working the coal, and it was partly to gain information on this point that I recommended horizontal trial drifts to be driven into a couple of the more promising seams, namely, the 11-feet seam in the Tíndharia ravine and the 7-feet one in the Chirankhola. Mr. Tyndall, Executive Engineer of the Dárjíling and Jalpigori Divisions, under whom the work was put, was unable to break ground at the latter during the rains. The drift into the Tíndharia seam had been driven 40 feet in from the out-crop, at the commencement of the rains, and the seam was reduced to 6 feet. It is, however, very probable that it again increases in thickness further in; and with a view to ascertaining the mean thickness of the bed here, and whether it maintains that thickness for some distance, or dies out partially or altogether, as well as to gain information as to the constancy or otherwise of the dip and strike, and whether the seam has been faulted or not, I

recommended that the drift should be continued to a length of 300 or 400 feet into the hill side. Mr. Tyndall thought he would be able to do this, although progress is not easy with ordinary kulis unaccustomed to mining work. Mr. Blanford states that in the Ráníganj field, the coal of the Ráníganj group is more regular and of more even quality than that of the Barákars, and the seams have a uniform thickness over considerable areas.* If then, as seems not improbable, the Dárjíling beds represent the Ráníganj group, it may be inferred with some probability that the seams possess a considerable degree of persistency.

Amount of coal.

With respect to the amount of coal existent, I have already alluded to the difficulty of determining the number of actual seams. The above list of out-crops is not a long one, but the time at my disposal only allowed of my going up the principal streams. An exhaustive search in all the smaller streams would undoubtedly increase it considerably. On the other hand, in some rivers, like the Tísta, where the rocks are fairly exposed, while seams of a few inches thick are numerous, not one of importance is visible.

Crushed condition of coal.

The crushing to which the coal has been subjected has induced a flaky structure, which renders it so friable that it can be crumbled into a flaky powder between the fingers with the greatest ease. It was simply dug out of the Tíndharia drift with kodálís, and a large proportion was extracted in powder, whilst what remained in lumps crumbled down on the application of the least violence; if handled roughly, or let fall a few inches, the lumps fell to pieces. The coal is not quite homogeneous in this respect; some samples from the Tíndharia drift were a little firmer than others, but the difference was trifling, and the coal at the end of the drift, 40 feet from the original out-crop, was as soft and flaky as at the surface. This proves beyond question that the flakiness is due entirely to crushing and not in any

* Vol. III, pt. 1, p. 40.

degree to surface weathering. Hence no material improvement in the firmness of the coal can be expected as the drift progresses, and there is every reason to suppose that the seams everywhere will, like this one, prove as crumbly in the interior as at the surface.

Composition.

The following assays made by Mr. Tween illustrate the composition of the coal; the specimens were first dried at 212°:—

Darjíling-Damúda coals.	Free carbon.	Volatile matter.	Ash.
Rakti naddi, 5′ 6″ seam	79·3	7·6	13·1
Cart-road, 6′ 0″ seam	74·1	9·0	16·9
Chirankhola naddi, 7′ 0″ seam	69·6	5·2	25·2
Tíndharia ravine, 11′ 0″ seam	66·3	12·4	21·3
Ravine south of Pankabári, 0′ 9″ seam ...	64·0	11·8	24·2
Average ...	70·66	9·20	20·14

The samples were all taken at the out-crop, within a foot or two of the surface, but the coal seems to be little altered by exposure. The following assays are of samples taken at intervals of 10 feet in the Tíndharia drift:—

Tíndharia ravine, 11′ 0″ seam.	Free carbon.	Volatile matter.	Ash.
At surface	66·3	12·4	21·3
10 ft. from surface	66·8	11·4	21·8
20 " "	67·5	14·4	18·1
30 " "	64·4	10·4	25·2

The coal in many seams has a brilliant sub-metallic lustre; in others it is duller. The former variety is more friable than the latter. The mineral is an 'anthracitic coal;' not a true anthracite, the volatile matter

in which does not exceed 5 or 6 per cent.; that of the 11-feet Tíndharia seam, which contains 12 per cent. or so of volatile matter, cakes to a slight degree in the fire. A qualitative analysis of the ash of this coal proved the absence of both sulphur and phosphorus, a most important advantage in the manufacture of iron.

Mr. Blanford gives assays of coal from seventeen of the Ráníganj mines.* The mean of these shows an average composition of free carbon 51·09, volatile matter 32·64, ash 16·27. If we assume, as we fairly may, that the Dárjíling coal, in its undisturbed state, had about the same composition as the Ráníganj, it follows that during and since the elevation and contortion of the former, and its associated beds, the coal has lost on an average more than two-thirds of its volatile matter. The percentages of free carbon and ash are thereby of course increased.†

Mining.

The question of whether the Dárjíling coal can be profitably delivered at the terminus of the Northern Bengal State Railway, say at Sukna, may be conveniently discussed under three heads, *viz.*, mining, conveyance of the coal to the foot of the hills, and conversion into a usable form of fuel.

The high inclination of most of the seams, as well as the softness of the coal, would necessitate a method of mining altogether different

* Vol. III, pt. 1, p. 189.

† A similar change has been shewn by Prof. H. D. Rogers to have taken place in the coal of the Appalachian field, where the strata are folded up in the Alleghany Mountains. In the western part of the field, where the bedding is level and unbroken, the percentage of volatile matter ranges from 40 to 50 per cent. "Eastward of this, on the Monongahela, it still approaches 40 per cent., where the strata begin to experience some gentle flexures. On entering the Alleghany Mountains, where the distinct anticlinal axes begin to show themselves, but before the dislocations are considerable, the volatile matter is generally in the proportion of 18 or 20 per cent. At length, when we arrive at some insulated coal-fields associated with some of the boldest flexures of the Appalachian chain, where the strata have been actually turned over, as near Pottsville, we find the coal to contain only from 6 to 12 per cent. of bitumen, thus becoming a genuine anthracite." (Lyell's Elements of Geology, sixth edition, p. 499.—Coal containing as much as 12 per cent. of volatile matter can scarcely be considered a true anthracite).

from that pursued in the Ráníganj collieries, where the greatest dip of the worked seams does not, as I am informed by Mr. Hughes, exceed ten or twelve degrees. Coal mining in highly inclined strata is always more difficult than in horizontal ones, but in many European fields, like those of Belgium, Westphalia, and some of those in England, fuel is profitably extracted from highly contorted seams. Where the folds of the strata are on a sufficiently large scale, so that the dip is tolerably constant for some distance, the coal can be worked at any inclination. But when, in addition to such larger curves, the seams are further crumpled up by other contortions on a minor scale, the difficulties are vastly increased, and may become so great as to render the coal valueless. Now, in the previous part of this report, I noticed several instances in which the Dárjíling seams are affected in this way, or where they are crushed into small and violent contortions, and even doubled back sharply on themselves. This is decidedly the most unfavourable feature present. The coal in many places will be unworkable in consequence, and it is even possible that this condition may be so prevalent as to prevent any portion being worked to a profit. The rapid variations in the thicknesses of the seams, a consequence of the same crushing, is another element to be taken into consideration, although of much less importance than the contortions. The crushing has, further, more or less shattered the sandstone and shale beds, or their equivalents where metamorphosed, so that these rocks cannot be expected to furnish as firm a roof as the same strata where undisturbed. The existence of faults and minor slips is also to be expected, and if of frequent occurrence, these would add another grave difficulty to working the coal. When describing the Damúdas, I noted some instances of the occurrence of such slips.

In the more highly inclined seams, the coal itself would form the roof of the galleries, and as it is far too soft to be self-supporting, there would be a heavy item of expense for timbering; an item which does not exist in the Ráníganj mines worked on the post and stall system, where

the roof is of sandstone or shale supported on stout pillars of coal. It is also to be remembered that the further a level is driven into the hill side, the greater will be the depth of superincumbent rock, and consequently the greater the expense for stronger timbering to withstand the increased pressure.

On the other hand, should the above difficulties not prove insurmountable, the coal could be mined, for a considerable time at least, by levels driven into the hill sides from the out-crops of the seams. The advantages of this would be important. The preliminary cost of shaft-sinking through unproductive rock would be saved, and also the expense of winding-gear to raise the coal, including the capital sunk in machinery, and the consumption of coal for winding-engines, such as are necessary in mines worked by shafts. The coal need merely be run out to the surface on tramways laid along the main levels. Further, pumping machinery and engine-power therefor, which form an important item of expense in shaft mines, would not be required, as the mines would drain themselves. The soft, friable state of the coal, and the high dips, would lead one to expect a considerable percolation of water from the surface. The Tíndharia drift, however, was quite dry in the interior, although a rivulet of water was trickling down the hill side directly above it. The surface clay no doubt protects the out-crop, and it would probably do so in many other cases also. In a thoroughly wet mine, it is to be feared that the water would render the already soft coal so yielding that the difficulty of keeping up the roof would be considerably increased.

The softness of the coal, although so disadvantageous in other respects, has at least this in its favor, that the work of 'getting' the coal would be easier. Instead of the laborious 'holing under', and subsequent breaking down by wedges or blasting, that is employed in most mines, nothing is requisite but to dig the coal out with kodálís and picks, as was done in the Tíndharia drift.

It may be confidently asserted that no risk is to be apprehended from fire-damp within any distance from the surface that the mines are likely to attain. As such is practically unknown in the Damúda coal of the Ráníganj mines,* there is little to fear from the same coal after it has lost two-thirds or three-quarters of its volatile matter, from the disengagement of which the fire-damp originates. It is no doubt possible that some of this disengaged gas may still remain stored up at a considerable depth, but it is highly improbable, taking into account the disintegrated state of the coal and the disturbed condition of the beds it occurs in.

Another point in favor of the Dárjíling coal is the almost total absence of trappean intrusions, which do great injury to the seams in some of the fields south of the Ganges.†

Carriage.

If the results of the trial drifts should prove sufficiently encouraging to warrant an attempt to work the coal on a commercial scale, the neighbourhood of Selim Hill would be the most favorable place at which to begin operations. Out-crops of fair thickness occur more plentifully there than along most other parts of the Damúda band, and the Chirankhola and Tíndharia seams, which are amongst the thickest yet known, are close to the cart-road, although several hundred feet below it. As a temporary measure, the coal could be brought up to the road on mules or cattle, along paths which would cost a very trifling sum, and then carted down to Sukna. The distance along the road, from the place where the Damúda band crosses it to the foot of the hills, is eight miles, and the difference of level, as measured by aneroid, 1,800 feet. The distance in a straight line is only three miles. If, subsequently, the out-turn should be sufficiently large, it would of course be necessary to make more complete arrangements, the plans which strike one as the simplest being either a tramway along the side of the road or a direct wire-tramway.

* Vol. III, pt. 1, p. 174.

† Vol. III, pt. 1, p. 146.

I observed no good seams near Ráni Hát, but a closer search might discover such. Their absence, indeed, would be another point against the coal, as showing that the seams near Selim Hill are not continuous for two miles to the eastward. If found, the coal could be taken down the easy gradient of the diluvial Ráni valley, and thence across the Terai to Sukna, a distance altogether of about six miles.

To bring the coal away from the neighbourhood of the Mahánaddi, it would be necessary to construct a road or tramway down the gorge of that river—about three miles measured along the bed of the stream, the distance from the debouchure to Sukna being three more. But this of course would not be undertaken until after mines had been opened near Selim Hill, and unless they turned out well.

Conversion into usable fuel.

The coal, as extracted from the mine, being in powder, or, at best, in lumps which crumble into powder on the application of the least violence, it manifestly cannot be used in its natural state.* It must be artificially compacted before it can be utilized as fuel for locomotive purposes.

Two ways of doing this present themselves—namely, coking and conversion into patent fuel. The Government of Bengal has directed one hundred máns to be sent to Calcutta for trial by both methods, but this has not yet arrived. Meantime, I may give the results of some experiments on a small scale which have been made.

* A small quantity of coal from the Tíndharia 11-feet seam was raised by Mr. Partridge, the owner of the Tíndharia estate, before the drift was opened, and an endeavour made to use it, in its natural state, for working the steam-engine which drives the tea-rolling machines. I am indebted to Mr. Montfort for an opportunity of witnessing an experiment of this kind. The furnace was being stoked with wood, and the engine working at 25lbs. pressure, when the coal was added in fragile lumps and powder, a good deal of which fell at once between the fire-bars into the ash-pit. The coal caked slightly, so as to admit, after a short time, of being gently stirred and broken up, but being mostly in powder when shovelled in, the fire was too much choked to allow sufficient draft, and the pressure soon sank from 25 to 15lbs.

Of the coals mentioned at p. 54, the Tíndharia, which contains about 12 per cent. of volatile matter, and which cakes slightly in the open fire, yields a firm hard coke when the powder is ignited in a covered crucible. Coal from the Rakti and Pankabári seams does not coke at all, although the assay of the latter agrees closely with that of the Tíndharia. It is a well-known fact that the coking property of coal does not depend solely on the percentage of volatile matter, although a certain amount of such is indispensable. Much of the Dárjíling coal is too near anthracite to give promise of being convertible into a good coke, and the above experiments seem to indicate that some of it will not coke at all. The following table shows the amount of free carbon and ash, after the elimination of the volatile matter, in the coals mentioned at p. 54.

		Carbon.	Ash.
Rakti naddi	5′ 6″ seam	85·8	14·2
Cart road	6′ 0″ „	81·4	18·6
Chirankhola naddi	7′ 0″ „	73·4	26·6
Tíndharia ravine	11′ 0″ „	75·7	24·3
Ravine south of Pankabári	0′ 9″ „	72·5	27·5
	AVERAGE ...	77·8	22·2

As artificial fuel the coal promises to turn out well. Mr. J. Grant of Barákar, who has had the management of patent fuel works at Ránίganj, was kind enough to experiment on a few pounds of dust-coal from the Rakti naddi 5′ 6″ seam. The ingredients used were in the following proportions :—

Dust-coal		... 1 ton.
Starch, composed of	Flour ...	... 12 to 16 lbs.
	Water ...	... 30 to 35 gals.
Crude carbolic acid		... 1 pint.

After being well mixed, the composition was pressed, by hand merely, into small cylindrical vessels, and the cakes subsequently allowed to dry. They were then almost as firm as average patent fuel; and Mr. Grant is of opinion that, when pressed by machinery, the bricks could be turned out as hard as ordinary Indian coal in the block. A couple of the cakes were broken up and tried by Mr. Hughes on a smith's hearth at the Mint. The fuel burned clearly, with little flame, and afforded a strong welding heat. It stood the blast without crumbling, and left but little clinker. It should be remarked, however, that the Rakti naddi coal has the best composition of any as yet assayed. The amount of ash in the Dárjíling coal is greater than that in Ráníganj, but the higher percentage of carbon fully compensates for this. The assays indicate that the heating power of average Dárjíling coal is above that of average Ráníganj, and nearly equal to that of the very best seams. The best Dárjíling is superior to the best Ráníganj.*

Mr. Grant estimates the approximate cost of making the coal into artificial fuel as follows :—

	Rs.	A.
Disintegrating the smalls with Parr's patent machine, about ...	0	2
Flour (say rice)	0	8
Crude carbolic acid	0	4
Moulding	0	2
Drying	0	1
Engine-power	0	1
Total per ton ...	1	2

The first item would not be necessary in the case of most, at least, of the Dárjíling coal, as it is already in a sufficiently disintegrated state. Ample water-power could be supplied at Sukna by an aqueduct from the Mahánaddi, thereby saving the consumption of coal for engine-power.

* *Vide* Records of the Geological Survey of India, Vol. VII, pt. 1, p. 20, for assays of the best Ráníganj coals.

The cost of manufacture may therefore be taken at one rupí a ton, or perhaps rather less.*

Relative cost of Ráníganj and Dárjíling coal.

The question of the profitable workability of the Dárjíling coal of course depends on whether it can be delivered for use at Sukna, and the northern part of the railway, as cheaply as Ráníganj coal; in other words, whether the expenses of mining the highly inclined and much contorted Dárjíling seams, carrying the coal to Sukna, and converting it into usable fuel, will not exceed the cost of the easily mined Ráníganj coal, plus carriage to the same place. I am indebted to Mr. Prestage, Agent of the Eastern Bengal Railway, for the following estimate of the cost of Ráníganj coal delivered at Sukna *viâ* the East Indian and Eastern Bengal Railways:—

	Rs.	A.
Cost per ton of Ráníganj coal delivered at Sámnaggar on the Eastern Bengal Railway	7	12
Loading at Sámnaggar	0	4
Carriage to Kushtia	3	8
Unloading at Kushtia	0	4
Ferry across Ganges to southern terminus of Northern Bengal State Railway	0	14
	12	10
Carriage by Northern Bengal State Railway to Sukna, 200 miles (actual cost)	3	0
Cost per ton at Sukna	15	10

This route includes carriage from Ráníganj to Biddabatti (106 miles) by the East Indian Railway, transport across the Húglí to Sámnaggar, carriage from Sámnaggar to Kushtia (95 miles) by the Eastern Bengal Railway, and transport across and up the Ganges (about 20 miles) to the Northern Bengal State Railway terminus, or in all 201

* This is exclusive of the cost of machinery and plant, which Mr. Grant estimates at about £900, for a daily outturn of 50 tons.

miles of railway carriage and two ferries. The two main alternative routes are—1*st*, from Ráníganj to Rájmahál by rail (173 miles), and thence down the Ganges for about 130 miles; and, 2*nd*, from Giridi (Karharbári) to Manghír by rail (137 miles), and thence down the Ganges for about 260 miles. Both these routes have the advantage of involving only one shipment into boats. The following are approximate estimates of the cost of transporting coal by them:—

Viâ *Rájmahál.*	Rs.	A.
Cost of coal at Ráníganj per ton	3	8
Loading at Ráníganj	0	4
Carriage by rail to Rájmahál	6	12
Shipping at Rájmahál	0	4
Carriage by boat to terminus of Northern Bengal State Railway	1	4
	12	0
Carriage by rail to Sukna	3	0
Cost per ton at Sukna	15	0

Viâ *Manghír.*	Rs.	A.
Cost of coal at Giridi	3	8
Loading at Giridi	0	4
Carriage by rail to Manghír	5	11
Shipping at Manghír	0	4
Carriage by boat to terminus of Northern Bengal State Railway	2	8
	12	3
Carriage by rail to Sukna	3	0
Cost per ton at Sukna	15	3

Thus it appears that Ráníganj or Karharbári coal cannot be delivered at Sukna under about Rs. 15 a ton. The actual cost of raising the coal at Ráníganj is, as I am informed by Mr. Hughes, about Rs. 1-4 on an average, or, including cost of management, rather less than Rs. 2 a ton.

The cost of carrying the Dárjíling coal to the foot of the hills by tramway, would probably not exceed a few annas a ton. Allowing, however, Rs. 3 for carriage in the first instance by carts, we have roughly—

	Rs.	A.
Carriage to foot of hills	3	0
Conversion into patent fuel	1	0
Cost, exclusive of mining, at Sukna	4	0
Carriage by rail to southern terminus of the Northern Bengal State Railway	3	0
Cost, exclusive of mining, at southern terminus of Northern Bengal State Railway	7	0

as compared to Rs. 15 a ton at Sukna and Rs. 12 at the southern terminus for Ránígan coal. This leaves a margin of Rs. 11 in the former case, and Rs. 5 in the latter, for the cost of mining the Dárjíling coal. If, therefore, the difficulties of mining the latter could be overcome at over double the expense of raising the Ránígan coal, the Dárjíling coal would pay at the southern terminus, and it would pay at Sukna if it could be brought to bank at over five times the expense of raising the Ránígan coal.* If we allow, say, 8 annas a ton for carrying the coal to Sukna by tramway, the margin for mining will be still larger. Serious, therefore, as are the difficulties to be encountered—difficulties which, it is not to be concealed, may prove insurmountable—the Dárjíling seams are clearly well worth a fair trial; and I would decidedly recommend that the experimental drifts be carried on.

Graphite.

I have already explained that the carbonaceous shales of the Damúdas are, in their most highly altered condition, converted more or less into a graphitic schist, and that similar beds are occasionally met with in the Dáling beds. The change, however, of the carbon from the

* This is on the assumption that the coals are of equal heating power; as I have shown, the Dárjíling has some advantage in this respect.

amorphous to the graphitic condition is, as far as my observations go, never complete, and is generally very partial indeed. The following assays* of semi-graphitic Damúda schist from the Rakti naddi, and of so-called graphite collected by Captain Sherwill, and now in the Geological Survey museum, show how small the percentage of carbon is:—

	Ash.
Rakti naddi	92·0
Near Pankabári (Sherwill)	83·8
Near Karsiáng (Sherwill)	84·6

The ash consists mainly of quartz and other silicious matter. It is scarcely necessary to say, that even if all the carbon were true graphite, a mineral containing 85 per cent. of ash is commercially worthless. It is no doubt possible that purer layers may exist; fair specimens of graphite have been obtained in the North-Western Himalayas† from strata similar to the Dáling beds, and possibly including Damúda rocks. I have never seen such, however, from the Dárjíling hills, and it is not probable that any really valuable masses of the mineral will be found. Specimens of the Kumáon graphite even, which have been sent to England for the opinion of manufacturers, have been pronounced by them as useless, or, at best, as not worth more than £5 a ton.‡

Chapter VII.—*Iron—Copper—Lead.*

Iron.

Lohárgarh.

There is a strong ferruginous band included in the Tertiary sandstones of Lohárgarh.§ The out-crop runs along the southern brow of the hill, with a thickness near the centre of perhaps 40 yards. The length of the out-crop being about a mile from east to west, or between the points where the band disap-

* Made by Mr. Hughes.

† Vol. III, pt. 2, p. 180.

‡ Jour., As. Soc., Bengal, Vol. XXIV, p. 203.

§ Dr. Hooker erroneously states (Himalayan Journals, Vol. I, p. 402), that the iron ore is wholly superficial.

pears below the alluvium, there is clearly an almost unlimited supply of ore. It is, however, of poor quality, the better portions containing only about 30 per cent. of iron, as shewn by Mr. Tween's assays—

No. of assay.				Percentage of iron.
1	...	...	...	30·8
2	...	...	...	28·7
3	...	...	...	32·3

The ore varies from a strongly ferruginous clay to an impure brown hematite, and has frequently a pseudo-brecciated aspect. It is not smelted by the natives, although there are vague traditions of its having been once worked, and of hammers still to be seen on the hill, so heavy that no one can lift them! The Chenga naddi brings down lumps of ore, an assay of one of which gave 39·6 per cent. of iron, but the lumps which stand such water-transport are the tougher and purer, or less clayey, portions.

Taking into account the poorness of the ore, and the facts that there is no considerable supply of limestone within 60 miles (unless in the unexplored country of Nepál to the westward), and that the Dárjíling coal, if practically workable, will certainly be more expensive at the mines than Ráníganj coal at the pit's mouth; also that wood is already growing scarcer and dearer in the hills west of the Tísta, owing to the demand for tea-making, there is little reason to suppose that iron works could ever be profitably established at Lohárgarh. In other parts of the country, more centrally situated, cheap coal and good ore are found together.

Síkbhar.

A valuable bed of iron-ore was discovered four years ago, about a mile east-south-east of Síkbhar. It is two or three hundred feet above the bed of the Rer, and some three thousand feet above the sea. It has, as yet, only been worked at two spots, about two hundred yards apart. The section at the eastern digging includes actinolite rock, with some quartz- and talc-schist containing octahedrons of magnetite; this is covered by the band

of ore, which seems to be about 20 feet thick, but it is obscured a good deal by surface soil. Above it, is more actinolite rock with crystals of magnetite, and then fine-grained gneiss dipping north-east at 30°. The magnetite of the main band occurs as an aggregation of irregular crystals about the size of peas. These cohere but slightly to each other, so that the rock is easily crumbled. In places the ore is pure magnetite, but more usually it includes a varying proportion of actinolite. At the other spot where the ore has been worked, it is a schist, composed of magnetite, micaceous hematite, actinolite, and talc, irregularly interbanded; the last three also including octahedrons of magnetite. Specimens of both kinds of ore have been assayed by Mr. Tween with the following results:—

		Percentage of iron.
Magnetite ...	...	... 71·50
Micaceous hematite	...	... 59·89

Neither contain any phosphorus or sulphur.

The ore has been smelted at Síkbhar, but to a very trifling extent.* At the time of my visit there were only two furnaces, one of which was new. Neither was in blast at the time, but the method of smelting seems to be quite similar to that usually practised in Bengal. The micaceous hematite is not used, as it is said to yield a soft iron, unsuited to the manufacture of knives, &c., and it occurs besides in comparatively small quantity. The magnetite is well suited, in its texture, to native furnaces, from the ease with which it is crumbled down into convenient sized grains. It is more difficultly smelted than the micaceous hematite, but the 'kámís' (as the Nepáli workers in iron are called) assert that it yields a steely iron peculiarly well suited for making kúkrís and báns, from its combination of hardness and tóughness. The raw spongy iron is sold at Síkbhar at six sírs per rupí. By the kámís it is re-heated and hammered out into small bars, which are

* The outturn, according to Jítman, a kind of munshí at the mines, has been only 80 máns of iron since the mine was opened.

doubled up and hammered out again. This operation is repeated two or three times before the iron is finally worked up into kúkrís, &c., which are tempered by heating and plunging into water.

The deposit is a valuable one; as will have been seen from the assays, the ore is extremely rich, and the quantity appears to be considerable, while the iron produced is of the best quality. The outturn might be largely increased, and a dozen or more native furnaces easily kept in blast. There is abundance of wood for such in the Rer valley, the upper part of which is entirely covered by virgin forest. At some future time the locality may attract notice for the production of a high-class iron on a larger scale. The workability of the coal will greatly affect this question, but the want of flux within a moderate distance must always be a drawback to iron-smelting in the Dárjíling hills. The conditions are not such as would induce one to look to them during the infancy of iron-smelting on European principles in this country.

Rangu naddi.

The actinolite rock, which accompanies the magnetite, is a peculiar variety of rock which I have not seen elsewhere *in situ*. Pieces of a similar stone are, however, brought down by the Rangu, a stream which joins the Tísta south-west of Kálingpung. The bed it comes from may be the same as that at Síkbhar, and a close search towards the head of the Rangu might be rewarded by the discovery of accompanying magnetite.

Sakkam-Chu.

Blocks of magnetic iron schist are washed down by the Sakkam river south of Dálingkot. The rock is composed of magnetite and quartz, the grains of each being sometimes distinct, but more usually intimately blended, so that the rock becomes almost compact.

Ma-Chu.

The Ma-Chu brings down large lumps of micaceous hematite. The hills through which these streams flow are uninhabited, and covered by dense forest.

COPPER.

The method of copper-mining adopted in Dárjíling is very similar to that generally pursued in India in most native mining operations. The mines greatly resemble magnified rabbit-holes; meandering passages are excavated with little or no system; and although some precaution is taken to support the roof in the more shaky places by timber props, the number of galleries fallen in show how inefficiently this is done.

Method of mining.

The passages average about a yard in height and width; but where the rock has not yielded a paying proportion of ore, they are contracted to a size barely sufficient to admit a man's body. Access to the interior of the mines, therefore, is gained by crawling on 'all fours,' and in the narrowest parts, by lying flat on the face and progressing after the manner of serpents. As a natural consequence of such a primitive system, the excavations cannot be carried beyond a very trifling depth, as compared to European mines; although taking the actual risks incurred into count, and imaginary dangers, which the stillness and darkness within the bowels of the earth are not calculated to dispel from the minds of a simple, superstitious race, no little courage is shown by the miners in excavating as far as they often do.

The tools generally used are an iron hammer and a round pointed chisel, which is held by a strip of split bamboo twisted round it. Small picks are also sometimes employed.* The lights used are thin strips of dry bamboo, a bundle of which the miners take to work with them; they say that the smoke is less irritating to the eyes than that from other kinds of wood. They are, I believe, all Nepálís: the Lepchas never engage in such occupations.

The ore, which is copper pyrites, is brought from the mines in small bamboo baskets of an elongated form, so as to be readily taken along the narrow passages.

Dressing of the ore.

* Illustrations of these tools and of the smelting furnace are given in Percy's Metallurgy (Vol. I, p. 388). Mr. Blanford mentions that in the Mahánaddi mine, the rock was loosened by lighting fires against it.

After a preliminary breaking-up of the larger pieces and rejection of the refuse, the picked ore is broken up small on flat stones, with hammers formed of suitably-shaped pieces of quartzite, or other hard rock, tied into forked sticks. Subsequently it is pounded to a coarse powder with heavier hammers of the same kind.

The powder is washed in troughs made of rough planks fixed on the ground, one forming the bottom, which has a slight incline, and the others fixed on edge. In form and size the troughs resemble small coffins, but the top and lower end are open. A small stream of water flows though, which is regulated in quantity by a dam of clay at the upper end. A hollow is made in the dam to allow a sufficient stream to flow into the trough, while the surplus water runs off by another channel. The ore is continually agitated by hand, or with a small basket-work shovel, and moved towards the upper end of the trough, by which means the larger fragments of copper pyrites, and of mundic if the ore be contaminated with it, are collected there, and the lighter residue carried lower down. This residue, which still contains some ore, is ground in hand-mills similar to those used in India for grinding corn, with grinding surfaces formed of slabs of gneiss. It is then re-washed in the same way as before, and the same operations sometimes repeated on the residue. The ore from the different washings is mixed together, and is ready for smelting. Most of the dressing operations are done by women.

Smelting.

The smelting-furnace is generally built with some neatness, of refractory clay; but in its ruder form consists merely of a hole dug in the ground, with a low clay rim along the sides and front, and a higher one, or a flat stone, at the back; the inside is plastered with refractory clay if that of the ground itself be not sufficiently infusible. The furnace is about 18 inches deep, a foot square at the top, and tapering a good deal towards the bottom. When it is dry, small charcoal is filled in to a depth of about a foot, and beaten down by a wooden rammer till a saucer-shaped

floor of coarsely powdered charcoal is formed, sufficiently compact to prevent the products of the smeltings sinking into it. These protect it from the blast, and it is besides too compact to burn easily. There is no orifice in the lower part of the furnace. Two clay tuyeres dip nearly vertically about 3 inches into it from the top, and are respectively connected with skin bellows by horizontal tubes about a yard long. The tubes are formed of clay mixed with chopped straw, and are moulded on a straight stick, which is subsequently withdrawn.

The furnace thus prepared is lighted up with charcoal and the bellows at each side worked alternately. When at its full heat, the powdered ore is sprinkled in at short intervals, until a sufficient amount of regulus, or 'cheku' as it is called by the smelters, has collected at the bottom of the furnace, covered by the lighter slag. The charcoal is then raked away, and the surface of the slag cooled with a whisp of wet straw tied to a stick. The solidified cake is removed and the fresh surface cooled; in this way the slag is taken off in two or three successive cakes, leaving the heavier and more perfectly fluid regulus behind, which is afterwards cooled and extracted.

The regulus (which contains some metallic copper disseminated through it, especially in the form of filiform crystals lining the cavities of the vesicular mass) is pounded and ground, mixed with an equal amount of cow-dung, and made into balls about the size of oranges. After drying, a quantity of these are spread on a layer of charcoal in a place surrounded by stones, and covered by more charcoal. The whole is then ignited, and the regulus thus roasted with free access of air. The roasted balls are subsequently crumbled down and ground, and the powder sprinkled into the furnace in the same way as the original ore. The slag, when the operation is finished, is cooled and removed in cakes, leaving a fluid mass of metallic copper at the bottom of the furnace. The copper is sold in this state at the rate of Rs. 2-8 per three sírs, which is equal to about 10*d.* a pound. It is still vesicular and brittle, and is re-fused before being wrought into manufactured articles, the refined

copper amounting, it is said, to 13 chatáks per sír ($\frac{13}{16}$ths) of the crude.*

Mode of occurrence of the ore.

Altogether there are over a dozen localities in the Dárjíling territory and the Western Duárs where indications of copper have been observed. The examination of these leads to some important generalizations. *1st.*—With the exception of some copper near Baxa in the rocks of the Baxa Series, all the known copper-bearing localities are in the Dáling beds. Some are, it is true, situated in the transition rocks between the Dálings and the gneiss, but none in the genuine gneiss itself. *2nd.*—The ore in all is copper pyrites, often accompanied by mundic. Sulphate, carbonate and oxide of copper are frequent as results of alteration of the pyrites, but they occur merely in traces. *3rd.*—The ore occurs disseminated through the slates and schists themselves and not in true lodes.†

Copper localities. Pankabári.

Mr. Piddington describes specimens of hornblende rock containing iron pyrites with a trace of copper from the neighbourhood of Pankabári.‡ I obtained a lump of clay-slate containing similar pyrites from the bed of the Bissarbatti stream.

Ráni Hát (1).

In the bank of the Ráni naddi, rather more than a mile above Ráni Hát, a couple of trial excavations have been made about twenty yards apart. One is in quartz-schist, dipping north 15° west at 40°, through two or three layers of which, of

* Bisman, the lessee of the Mangphu copper mine on the Tísta, informed me that the yield from the various operations at his mine were about as follows:—1 mán (maund) of picked ore yields 6 or 7 sírs of washed ore; 7 sírs of washed ore yields 4 of regulus; 4 sírs of regulus yields 1¼ sírs of copper, or about 3¾ to 4¼ per cent. of copper from the picked ore. Eight or 9 sírs of regulus are obtained at one operation in about six hours, and 3 or 4 sírs of copper in about three hours. These figures are not altogether reliable.

† Mr. Taylor, a practical miner who examined a mine in the Mahánaddi valley when it was at work, and whose report thereon is given in the appendix, speaks of the 'lode' there. I believe, however, he must have used the word merely to express a metalliferous band of rock, without reference to its mode of origin.

‡ Journal, Asiatic Society, Bengal, Vol. XXIII, p. 479.

half an inch or an inch in thickness, iron pyrites with a trace of copper is disseminated. The other is in hornblende schist, and the pyrites here is even less plentiful than in the first. The excavations were not sufficiently promising to induce the miners to continue them beyond a few feet.

Ráni Hát (2).

About half a mile to the east of the above locality, and perhaps in the same stratum, copper has been worked rather extensively. The spot is a mile north of, and 1,100 feet above Ráni Hát, near the head of the Chochi stream. The rock is quartz with some hornblende-schist dipping north at about 35°. The copper-bearing stratum averages about 18 inches in thickness. Here and there throughout it copper pyrites is disseminated in little layers parallel to the bedding. These layers are not solid ore, but throughout them the pyrites is more or less thickly disseminated, while elsewhere in the cupriferous stratum the ore is absent or only visible in specks.

There are six galleries now visible, the roof in five of which has fallen in within 30 feet or less from the mouth. The remaining passage is still open, and extends to a length of over 90 feet. It, like all the others as far as they are open to inspection, is driven from end to end through the same stratum; and thus, as the passages run more or less nearly with the dip of the beds, they descend at an angle of about 35°. Although there had been an inch of rain a day or two before my visit the mine was quite dry. As the hill-side here is very steep, and the mine is near the watershed between two watercourses, there is naturally but little water to drain in. The mine was worked for a month or two last year, but is now abandoned for the time being.

Mahánaddi.

There is an old mine several hundred feet above the Mahánaddi on the west side, near the mouth of the Baffupáni, which has been deserted for many years, and all the openings have fallen in, so that very little can now be seen. The gangue is hornblende-schist with quartz- and chlorite-schist dipping north 40°

west at from 30° to 40°. The main cupriferous stratum seems to be about 2 feet thick, throughout which the ore, with mundic and traces of blende, is disseminated, as in the Ráni mine, in little strings or clustered particles and in specks. Several openings have been made into this stratum; and 6 or 8 feet above it, where the rock is also slightly cupriferous, there is a trial opening, which, however, was not carried beyond a yard or two.

It will be observed that the last three copper-bearing localities are situated a little south of the gneiss in the transition beds between it and the Dálings, and that the rock is all quartzose hornblende-schist, on the same horizon. It is not improbable that all belong to one cupriferous stratum extending at least from north of Ráni Hát to the Mahánaddi, and it is along this line that any further search for copper in the neighbourhood should be made.

No one with me in the field knew of any mine in the Mahánaddi valley but the above. It would appear, however, from Mr. Taylor's report, given in the appendix, that more than one mine was worked there some twenty years ago. The mine he examined was probably different from the above, as he says the 'lode' dips north at 30°; it was very probably in the same stratum however, as his description agrees closely with my observations in other respects.

Mr. H. F. Blanford also visited one of these mines about the same time as Mr. Taylor; he describes the cupriferous stratum as small, and the ore as very poor with a large admixture of mundic.*

Mangwa.

Mr. Piddington mentions iron pyrites with a trace of copper from Mangwa, a village near the next mentioned locality,† but no mine appears to have ever existed there.

* Percy's Metallurgy, Vol. I, p. 388.

† Journal, Asiatic Society, Bengal, Vol. XXIII, p. 479.

Pashok.

The principal Pashok mine is on the hill-side above the Rangiák stream. It was worked in Dr. Campbell's time by a man named Rájman, who is said to have lost heavily by it; afterwards by Bhotu, and lastly by another Rájman, by whom it was abandoned three years ago after the discovery of the Mangphu mine. The cupriferous stratum is quartzose hornblende-schist, dipping south-west at 15°, through which the ore, with mundic, is very sparsely disseminated. Mr. Piddington's assay of a sample from this locality yielded only 1¾ per cent. of copper.* There is another older mine, close to the bank of the Rangiák, which has entirely fallen in.

The Pashok and Mangwa copper localities appear to be on the same horizon as the Mahánaddi and Ráni Hát.

Rangbong naddi.

Copper is said to have been recently found near the head of the Rangbong, west of Pashok, but I did not hear of it until after I had left the neighbourhood.

Rattu.

The Rattu mine is in Independent Sikkim, but I visited it as it was being worked at the time. The rock is grey clay-slate with interbanded lenticular layers of quartz, through both of which the ore occurs, but chiefly in the latter. The strata dip at high angles, and vertically, with an irregular strike from north-east—south-west to north—south. The mine is in a ravine which runs nearly parallel to the direction of the strike, so that the entrances cut across the bedding, but inside there are also drifts ramifying parallel to it. The mine is extremely wet, with rivulets of water running down some of the passages. The men are therefore unable to sink below the level of the stream outside into which the water drains.

The ore here is the best I have seen, and occurs in considerable quantity, as evidenced by the extent of the excavations. Several heaps of good picked ore, very free from mundic, were lying about; a care-

* Journal, Asiatic Society, Bengal, Vol. XXIII, p. 477.

fully selected average sample contained 9·1 per cent. of copper. A sample taken from a heap of pounded ore ready for washing gave 7·8 per cent. when assayed by Mr. Tween.

Kálingpung.

The mine about two miles north-east of Kálingpung is in wrinkled and wavy clay-slate dipping south-east at 60°, and containing irregular, more or less lenticular little seams of quartz parallel to the bedding, and interbanded layers of very hard and tough light grey quartzite. It is in this rock and in the quartz seams that the ore (with a little magnetic pyrites) mainly occurs, although a little is also visible in the slate itself. The proportion, even in the quartzite, is very small. The mine was worked a couple of years ago, but was given up on account of the hardness of the rock. There are two openings near each other, the larger of which extends about 40 feet along the strike of the beds, with a maximum depth of 10 or 12 feet.

Re Ung.

About a quarter of a mile above the mouth of the Re Ung a trial drift has been made some 20 feet above the bed of the stream. The rock, which is clay-slate with interbanded layers of quartzite, dipping north 30° east at 40°, contains copper pyrites disseminated through it, but in such small quantity that the drift was abandoned after a few feet of progress. This station is nearly on the same horizon as the Mangphu cupriferous beds.

Mangphu.

The Mangphu copper mine on the Tísta is the only one in Dárjíling territory that is worked at present. It was, as I was informed, first opened about four years ago, and it has the reputation of being the best mine in the district. The lessee last year was a Nepálí named Bisman; his lease expired on the 15th of November, and had not been renewed at the time of my visit in January, so that mining was temporarily suspended, and the men were engaged in smelting the small remainder of ore on hand.

The mines are on the hill-side on the left bank of the Tísta. The latest worked, which are said to have been the most productive, are

about 500 feet above the river. The rock is a light green and greenish-grey clay-slate containing irregular layers of a grey fine-grained slaty sandstone, and dipping north to north-east at from 30° to 40°. The ore, with which there is little or no mundic, occurs in both varieties of rock. Throughout the entire thickness cut through in the galleries (some 3 feet), cupriferous layers occur here and there, while in the intervals the ore only occurs very sparingly or in specks. The lenticular cupriferous layers, which are parallel to the bedding, vary in thickness up to several inches, or even occasionally, as Bisman told me, up to a foot. Throughout these the ore is more or less abundantly disseminated, and little nests or short irregular layers of the pure mineral sometimes occur as much as half an inch, or an inch thick. The main passages descend with the dip of the beds from the out-crop, the deepest being 46 feet in length. There are three others close to this, one of which has fallen in. They were perfectly dry in January.

Five feet below these galleries there is an abandoned trial opening, and another about 100 feet higher up, from both of which copper in small, but not paying, quantity was obtained. Seven hundred feet above the river there are several openings throughout a thickness of 20 or 30 feet of strata, which have been abandoned, and nearly all of which have fallen in. It appears then that throughout a thickness of at least 200 feet, these slaty rocks contain cupriferous bands at intervals, and that a few of these are moderately productive. But out of fifteen or sixteen galleries opened, the majority have been abandoned and allowed to fall in. Bisman informed me that only three had paid. As lessee of the mines, however, he would not be likely to unduly magnify their value, and it is possible that some of the abandoned galleries were given up from their having been driven as far as the miners thought it safe to go. If the information Bisman gave me be correct, the average yield of copper from the picked ore is about 4 per cent. He told me he had made 72 máns of copper (of 40 paka sírs) during his year's tenure of the mine.

Sampthar.

In a lateral ravine which joins the Lesu south of Sampthar, some indications of copper have been exposed by a landslip, and the out-crop was cleared for my inspection. The rock is clay-slate, with occasional lenticular layers of quartz, in which most of the copper pyrites, associated with mundic, occurs. These layers contain a considerable proportion of ore, but there were only two or three of them exposed, varying in thickness from 2 inches downwards. The dip of the beds is west 20° north at 30°.

Ravine west of Chel river.

Four years ago a small quantity of ore was extracted from a ravine west of the Chel by the same men who worked the next-mentioned mine. The slates here dip north at 40°; and Arjun described the seam as only 1 or 2 inches thick.

Chel river.

This mine, the mouth of which is on a level with the stream, is now completely filled with stones and water, so that nothing can be seen, except that it is driven into clay-slate dipping east of north at 30°. It is on the western bank of the Chel at a point where the river, which flows in two channels above, again joins into one. Arjun, a Nepálí, who was sent to show me the place, and who had worked in the mine, told me that the locality was indicated to him and others who were searching for copper about four years ago by some fishermen on the Chel, who had observed what they thought looked like ore. After much labor the miners succeeded in turning all the water to the eastern side of the channel, thus leaving the western bank dry. The mine was carried to some 20 feet from the surface, following the dip of the beds, the seam varying from about 4 inches to a foot in thickness, and Arjun described it as having been solid ore with little or no gangue (?). Twenty máns of copper was smelted during four months' work. The hot-weather had then set in, and seven men died of fever. Jangbir, the lessee of the mine, who had gone towards Dárjíling to sell the copper, also died, and hence the mine was abandoned. The seam, however, still maintained its full thickness, but its value is greatly diminished by its position. There

is no high ground near, so that it must be worked below the level of the stream, and in such slates the influx of water would undoubtedly be very great.

Chamurchí.

Copper is said to exist near Chamurchí in Bhután, and several years ago, as I was told by the headman of the place, some Nepális made a commencement of working it, but were driven away by sickness. The headman did not know the exact locality, but said it was a short way up the river from his village. I found a piece of quartzite in the bed of the stream containing copper and iron pyrites disseminated through it.

Baxa.

About half a mile west of Baxa there is a spot on the hill-side where copper has been found, but not worked. The rock is greenish slate with quartzose layers, the latter especially containing mundic with some copper pyrites, and the surface débris at the spot is cemented into a gossany breccia. The proportion of mundic is greater than that of ore.

Mr. Beckett, when Deputy Commissioner of Jalpigori, gave permission to some Nepális to work copper ore near Baxa, but I have no information as to whether they actually did so.

Summary of copper localities.

The localities in British Territory where copper is known to exist may be grouped thus :—

Mine now worked	Mangphu.
Mines abandoned, but still partially open ...	Ráni Hát. Pashok (1). Kálingpung.
Mines abandoned and wholly fallen in or choked up	Mahánaddi, Pashok (2). Ravine west of Chel river. Chel river.
Localities where trial openings have been made and abandoned	Pankabári. Ráni Hát. Mangwa. Re Ung.
Localities recently discovered and not yet tried beyond merely clearing the outcrop	Rangbong. Sampthar. Baxa.

It appears then that out of the above fourteen localities four have been tried by the native miners, but have not been considered sufficiently promising to induce them to go on. Of the mines now wholly fallen in or choked, Arjun spoke of that west of the Chel as very poor and unimportant, but he described the seam in the Chel itself as decidedly rich, compared to most of the others. I cannot say what degree of reliance can be placed on his account. Mr. Taylor describes the 'lode' he reported on in the Mahánaddi valley as 2½ feet thick, and estimates the yield "in places" at 12 to 16 per cent. of ore, which is equal to 4 to 5½ per cent. of copper. Mr. Blanford describes the ore from this or a neighbouring mine as very poor, with a large admixture of mundic. My own opinion of the mine near the mouth of the Buffapáni, judging from the little still visible, was not more favorable.

The proportion of ore now apparent in the Ráni Hát and Pashok mines is very small, but this cannot be considered a fair criterion of their value, as the miners would not be likely to abandon them if there were any tempting layers of ore exposed at the time. The same seam probably varies much in productiveness, and a mine would most probably be abandoned when the seam was least productive, although the percentage of ore might again increase if the work were carried on further. No very reliable opinion can therefore be formed as to the value of these mines in their present state, but there seems no reason to suppose that they were ever more than fairly productive to the native miners, if even always that. I think the Ráni is the better of the two. Mr. Piddington's assay of ore from the Pashok mine gave only 1¾ per cent. of copper. The proportion of ore at Kálingpung is about equal to that at Ráni Hát, but the rock is extremely hard and tough.

Work at the Mangphu mine had been suspended for a couple of months at the time I visited it, and the only ore yet unsmelted was some which had been powdered, and left uncovered exposed to the wash of the rain. I was therefore unable to get any average samples from considerable heaps. The proportion of ore, however, exposed in the

newest galleries was considerably greater than in any of the deserted mines, but several galleries and trial drifts had been abandoned. According to Bisman, the lessee, the average yield of copper from the picked ore is about 3¾ to 4½ per cent. This is equal to poor Cornish picked ore.

The Rattu mine in Independent Sikkim is, as I have said, the best I have seen, the picked ore there containing 8 or 9 per cent. of copper, which is slightly above the average yield of Cornish ore.

The exposure of the outcrops did not lead me to suppose that the Sampthar and Baxa seams would turn out above the average of those elsewhere.

It appears then that the best seams are fairly productive, while the working of others does not seem to have much more than covered expenses, and some have resulted in a loss. The miners have not a thriving look about them, and the number of deserted mines is in itself suggestive that copper smelting in the Dárjíling hills is not a very lucrative employment.

Conditions not encouraging to European enterprise.

The prospect cannot be considered very encouraging towards any attempt to work these mines systematically. No doubt the native miners make a living out of them, barbarous as their way of mining is. The chief disadvantages of that system, however, lie in the injury to the seam and the wastefulness by which the greater part of it is left behind in the mine, while the latter can only be carried to a trifling depth from the surface. The system is perhaps not greatly more expensive with regard to what ore *is* obtained than a more civilized method of procedure, as long as the mines are shallow. The miners may locate themselves at some likely-looking spot and make a profit if they gain sufficient ore to smelt a few mans of copper. If a venture does not turn out well, or when a locality is beginning not to pay, they have merely to pack up their skin bellows and a few tools and remove elsewhere, leaving behind them the remains of their clay furnaces and a few huts made of branches.

Lodes equal to the better Dárjíling seams would no doubt be sufficiently attractive in Cornwall to tempt speculation; but the conditions in an old mining country, where the requisite *personnel* and *materiel* are both at hand, can scarcely be compared to those in the Himalaya mountains. Metal mining under the most favorable circumstances must always be a speculative undertaking, as the rapid fluctuations in the value of mining shares and the long lists of non-dividend-paying mines in England abundantly shows. It cannot be asserted that an attempt to work some of the Dárjíling seams must end in loss, but the conditions are not such that one can feel very sanguine of success.

If any such attempt should be made, it ought to be confined at first exclusively to mining, and no expense incurred in preparations for dressing and smelting until it has been shown that there is a prospect of the mine yielding a fair return. The ore brought to grass meantime could be dressed in the native method, and sold to the native smelters, or sent to England, if it should be found advisable in the end to give up the project. It would, of course, be absolutely necessary that the work should be put under the superintendence of a skilled European miner. The workability or otherwise of the Damúda coal will have important influence on the expense of copper-*smelting* in the Dárjiling hills.

Leases.

I do not think the natives can be easily induced to adopt a better system of mining. It is that which they and their fathers before them have always practised; they have no one to teach them a better, nor capital, or perhaps inclination, to adopt it if they were taught. One step, however, in this direction might, I believe, be taken—by granting longer leases of the mines. The present system is to put up the leases to auction yearly; one which must foster a hand-to-mouth mode of working, as the lessee's interest is to get as much as possible out of the mine at the time, careless of what becomes of it afterwards. If he were sure of possession for a term of years, it would be more worth his while to attempt some degree of system. No doubt he can always retain possession by bidding highest,

but he has no guarantee that the bidding may not go above the real value of the mine. I think that if permission were given to work any of the deserted mines free for a year, so as to allow the miners fairly to test their value, and after that leases were granted for a term of years by tender or auction, men would be found willing to reopen some of them.

LEAD.

I have no information of lead having ever been worked anywhere in the present area. I observed, however, an indication of the metal in the Sakkam river, in the shape of a boulder composed of garnet and hornblende, containing some galena, with pyrites and magnetite disseminated through it. The boulder, of course, was washed from the upper part of the stream.

CHAPTER VIII.—*Lime—Building stone—Slate—Clay—Steatite—Salt-licks.*

LIME.

There are three sources from which lime is procurable in the area under discussion, namely, from the dolomite of the Baxa series, from the impure limestone beds of the Tertiaries, and from calcareous tufa. It is the last rock only that is, or, I believe, ever has been, burned for lime.

Dolomite.

Mr. Tween's analyses of the dolomite from the Títí naddi are as follows :—

	Light grey saccharoid.	White, almost crypto-crystalline.
Carbonate of lime	59·7	60·5
„ „ magnesia	37·8	38·7
Oxide of iron and alumina ...	1·0	·3
Insoluble	·8	
	99·3	99·5

The rock, therefore, contains an excess of lime over that in normal dolomite, and is almost quite free from impurity. A high range of hills is entirely formed of it, so that the supply is inexhaustible; but the dolomite hills west of the Tursa are just beyond the British boundary in Bhután, the authorities of which would no doubt demand a royalty for working the mineral. For the supply of Jalpigori the most advantageous locality is a ravine a little east of the Rekti naddi (north of the 21st boundary mark). The rock in the lower part is black slate, above which is dolomite, forming a naked precipice at the head of the ravine, from which numberless large and small blocks are washed down every rains, so that there is no necessity to quarry. A considerable quantity of gravel, and small lumps of a convenient size for burning, is washed across the frontier.

The dolomite east of Baxa is within the British boundary.

Tertiary limestone.

The clunch beds of the Náhan group are very frequently more or less calcareous. Sometimes the calcareous matter is segregated into nodules, and these even pass into short irregular beds of impure grey or yellowish limestone. Mr. Dejoux, Executive Engineer in charge of the Sealdah experimental cement works, has kindly analysed some rock of this kind from the Chirankhola naddi with the following result:—

Carbonate of lime	68·7
" " magnesia	1·7
Oxide of iron and alumina	1·3
Clay	27·4
Sand	·6
Loss	·3
	100·0

Mr. Dejoux is of opinion that the stone would yield a kind of natural cement, more especially a kind containing rather more clay than the above. The beds, however, are thin, not very frequent, and irregularly scattered through the clunch, so that no quarries, beyond per-

haps some small pits, could be opened. Considerable quantities of calcareous boulders are washed down by some of the streams, but they vary in composition from a rock like the above, containing 70 per cent. or so of carbonate of lime, to a merely calcareous clunch, so that it would be difficult to obtain a stone for cement purposes having a uniform composition. A rough approximation to the composition can be gleaned from the fracture, which is rough and uneven in the calcareous clunch; both becomes finer as the proportion of lime increases, until in a rock like that of which the analysis is given it is smooth and conchoidal.

One or two of the thickest beds of limestone have been marked on the map; but even these do not exceed a few feet.

Calcareous tufa.

The lime used in the Dárjíling district is derived entirely from calcareous tufa. In the Rumtek naddi, where a quarry is at present worked by a Lepcha, I had an opportunity of observing the way in which it is burned.

The kilns, which are over 15 feet in internal diameter, consist each of a circular wall about 10 feet high and 2 feet thick, built of flattish stones from the bed of the adjacent stream. The interstices on the inside are luted with clay, and at the bottom at opposite sides are two orifices, about 3 feet high by 2 feet broad, for the admission of air, and from one of which the lime is withdrawn. There is a rough shed close to the orifice, under which the lime is stored.

The kiln is filled to within 2 feet of the top with logs of wood, and then the tufa, in pieces averaging 2 to 4 inches long, is thrown in and piled up into a low cone, the edge of which is on a level with the top of the wall, and the apex some feet above it. After being lighted, the kiln burns for about a week, and when tolerably cool, the lime is extracted from below and slaked with water, in which state it is sold. The uppermost part of the heap of tufa, which is exposed to the air, and which merely acts as a blanket to keep that nearer the fire hot, is scarcely burned at all, and is returned to the kiln at the next

firing. The system of adding the fuel and limestone in alternate layers, and keeping the kiln continuously fed, seems to be unknown. I was told that the average yield per kiln at one operation is about 300 máns, and that the sub-contractor who burns the lime receives 8 annas a mán for it on the spot from the lessee of the quarry. The actual cost of lime-burning in the Dárjíling district (including quarrying the tufa, cutting wood, &c.,) seems to be about 6 annas a mán, but owing to the expense of carriage it was selling this year at Pankabári at Rs. 3 a mán and at Jallapahár at Rs. 2-6. The lime in the latter case came from a place in Sikkim, some miles across the boundary, at an elevation of 3,500 or 4,000 feet. From thence it had to be carried to over 7,000 feet at Jallapahár across the valley of the Rammán, where the elevation is only 1,600 feet.

The tufa is always nearly pure carbonate of lime, even when the rock from which it is derived is dolomite. Thus analyses of that from the Títí naddi gave the following results :—

	Ordinary porous tufa.	Crystalline tufa.
Carbonate of lime	98·10	98·50
" " magnesia	1·30	1·50
Oxide of iron, alumina, and insoluble matter...	·80	·06
	100·20	100·06

Both carbonates of the dolomite are converted into bicarbonates and dissolved by water holding carbonic acid in solution ; but the bicarbonate of lime being the less stable compound is decomposed first, with deposition of tufa, while the bicarbonate of magnesia is carried off in the water.

The tufa is nearly always porous, the crystalline variety being rare. There is a peculiar species of moss often seen growing on it, which the natives assert turns into, and is in fact the origin of, the tufa. I observed what probably gives rise to this idea in the ravine above mentioned east of the Rehti naddi. The water of the stream is so charged

with calcareous matter that the dead leaves and twigs in the bed are thickly encrusted with it. Deposits of tufa have been formed at every little cascade, on which the moss grows out more or less horizontally, and along the sprays which point downwards the water trickles from root to apex and then drips off. Thus little stalactites are formed, each of which encloses a spray of moss in the centre, and which gradually encroaches on the root; while the plant keeps pace in its growth at the other end, and crowns each stalactite with a living rosette.

The calcareous matter forming these deposits is derived from various sources; from the dolomite of the Baxas, the calcareous clunches and impure limestones of the Tertiaries, the calcareous sandstones of the Damúdas, and the occasional calcareous bands in the Dáling beds.

Tufa in Western Duárs.

As might be expected, the largest masses are found along the base of the dolomite hills; where there is what I believe may be considered, an inexhaustible supply of lime from this source, independent of the dolomite itself. At the Bandapáni waterfall (within the British boundary), where there is a series of rapids and cascades of perhaps 50 feet, the stream flows continuously on a tufa for at least two or three hundred yards, the thickness of the deposit, where seen at the lower end, being 7 or 8 feet. There is a thick deposit near the 20th boundary mark, which cements the talus at the foot of the hill into a coarse breccia. Close to the Tursa river there are masses of tufa at the foot of the hills, forming cliffs 30 feet high; and there are numerous masses where the Jángti naddi cuts through the dolomite. These are some of the localities in which I have observed deposits of the kind, but they are no doubt to be found in almost every ravine and watercourse.

The magnesian and pure lime from the dolomite hills is therefore well worth attention. It might be burned either close to the Tursa (a stream which is navigable for the largest dug-outs to the foot of the hills, and for larger boats to within a few miles of them), and thence taken down to the Bráhmaputra, or in the vicinity of Jainti Hill, east

of Baxa. The latter locality is, however, less favorably situated, as it is some miles from the Raidak, which is a smaller stream than the Tursa. When the Northern Bengal Railway is complete, the lime could also be burned at the western end of the range, carted to Jalpigori, and then taken by rail either to the foot of the hills at Sukna, or down country. By one or other of these routes it might compete with the Sylhet lime from Chátak over a considerable part of Lower Bengal, if not in Calcutta itself.

Tufa, derived probably from calcareous Tertiary beds, has been worked in a ravine off the Déma naddi for the supply of Baxa with lime. The deposit has recently, however, been buried by a landslip.

Tufa in Dárjíling district.

The tufa deposits in the Dárjíling district, which are derived, not from large masses of limestone, but from rocks generally containing only a small percentage of calcareous matter, are on a much smaller scale than those in the Duárs. It is from them, however, or from similar deposits in Sikkim that the lime used in the district is procured. Tufaceous masses seem to be more common along the Tertiary-Damúda boundary than elsewhere, probably on account of the issue of springs there.

The following list includes all the localities with which I am acquainted:—

1. West of Pankabári, in a watercourse 500 or 600 feet above the Bálasan, formerly worked, but now exhausted.

2. In the neighbourhood of the cart road, tufa is found in several of the watercourses a few miles from the plains; generally it does not exceed a few inches in thickness, covering the rocks in the beds of the nallas and giving them a rounded appearance as if all solid tufa.* Sometimes there are thicker accumulations. The bed of one steep watercourse I ascended was lined with it for 30 or 40 yards, the tufa hanging down here and there in stalactites. It is derived in this neighbourhood from Tertiary calcareous clunch, and has been worked in several places.

* It is generally very difficult to estimate the thickness of a tufa deposit unless a section is exposed by quarrying or natural fracture.

3. At the east side of the Mahánaddi, just north of the Damúda-Dáling boundary, tufa occurs in small quantity.

4. Tufa was formerly worked near the end of the spur at the junction of the Sibakhola and Mahánaddi.

5. A small deposit is said to have been found within the last few months on the hill side a little below the mouth of the Kuhi naddi.

6. Near the head of the Kuhi there is a deposit from which lime has been rather extensively burned within the last year or two.

7. Tufa occurs in small quantity near the head of the Sivok naddi.

8. It is found in considerable quantity in some of the ravines which join the Riyem near the mouth of the latter, but has not been worked as yet. The Tertiary rocks here are more than usually calcareous.

9. It was formerly worked at Pashok, but the locality is now exhausted.

10. Tufa is said to have been lately found near the head of the Rangbong naddi (west of Pashok).

11. There are two abandoned quarries near the head of the Sím naddi (north-east of Takda). The rock from which the tufa has been derived is a calcareous actinolite rock. By following the strike of this, other deposits would no doubt be found.

12. In the Sambúl naddi (west of Damsáng) there is a mass of tufa some 80 feet long and 20 high, with a thickness varying up to 2 feet or so. It was worked some years ago when Major Lance's bangalo at Damsáng was being built. There is a smaller deposit about 150 yards higher up stream.

13. Near the left bank of the Lesu, a little above the Fing or Thaffing naddi, there is a mass of tufa through and over which a spring of water issues. It seems to be more than a foot thick in places.

14. In the Rumtek naddi (a small tributary of the Lesu) tufa was being quarried this year from by far the largest deposit I have seen in the district. Part of it is concealed by surface soil, but the portion visible is about 150 feet long by 30 or 40 broad, with a thickness at the side, where it was being quarried, of 8 feet. A little higher up stream there is smaller deposit, and near the head of the naddi some of the watercourses are lined with tufa.

Building Stone.

There is little demand for other building stone than rubble; which is generally procurable from the rocks nearest at hand: coarse slate from the Dáling beds; gneiss, which usually is easily split into conveniently sized pieces; and, near the foot of the hills, the harder Tertiary beds—are the varieties of stone mostly used for such purposes.

Freestone in blocks of any size could be procured from the Tertiary sandstones; but unless carefully selected its durability would be open to question. There is comparatively little stone from which good ashlar can be obtained in the older formations. The Dáling beds are mainly slaty. Good-sized blocks can be quarried from the gneiss in places, but generally it is too schistose to furnish such. A few of the Damúda beds of sandstone are also capable of being worked.

SLATE.

Shortly after my arrival in the district, my attention was directed to a reported discovery of roofing slate. On examination of the locality, however, I found that the slate was in no way superior to that frequently found amongst the Dáling beds elsewhere. From the best slate I have seen, slabs cannot be procured more than a few inches across, with a thickness of a quarter of an inch, and these are too brittle to trim well on the edges. Flagstones, for flooring purposes, could, however, probably be worked in some places.

CLAY.

The gneiss decomposes superficially into a light brown, very plastic clay. Both it and the clay resulting from the decomposition of the Dálings are used throughout the Dárjíling district for making bricks. Some of the Dáling slates decompose into a white clay which might be used for pottery. There is a quantity of this material near the right bank of the stream at the debouchure of the Sakkam. I am told that similar stuff is used in Sikkim for whitewashing.

STEATITE.

I have already (p. 35) alluded to the steatite found amongst the Baxa beds at the debouchure of the Tursa; which, Major Godwin-Austen states, has been used by the Bhutias for making cups, &c. The locality is across the boundary in Bhután.

SALT-LICKS.

So-called salt-licks are frequent along the outcrop of the Damúda rocks. They occur chiefly where there are seams of coal interstratified with sandstone, &c., and are resorted to by the wild animals of the jungle for the sake of the saline matter which effloresces to a slight extent on the surface of the beds. The ground is trodden down into a black mud by the feet of deer, rhinoceros, and elephants, the last of which dig out the coal with their tusks to a depth of several feet. The efflorescence is not of common salt, but of sulphate of soda which is probably formed by the oxidation of a trace of pyrites in the coal, and the reaction of the resulting sulphate of iron on soda washed out of the felspar which sometimes forms an ingredient of the sandstones.

APPENDIX.

From CAPTAIN H. C. JAMES, *Officiating Superintendent of Darjeeling, to* W. GREY, Esq., *Secretary to the Government of Bengal, Fort William,* —(*No.* 301, *dated the 23rd June* 1856.)

The Lieutenant-Governor is, I believe, aware that Mr. Hunt, the Railway Contractor of Mirzapore, stated, when in Calcutta, his willingness to send a practical miner in his employ, to ascertain the value of the copper veins in the vicinity of Darjeeling. Captain Taylor, the miner, arrived here in April, and I at once rendered him every assistance to enable him to visit the copper localities: the pathway to the principal mine was in such a bad state that I had it put in order, and erected a small shed for Captain Taylor to reside in during his stay at the mine.

2. I now beg to enclose Captain Taylor's Report, which, I regret to say, is not of a very favorable character. I have had much conversation with Captain Taylor since his return from the mine, and I learn from him that he does not think there is a chance of any richer ore being met with, unless a "level" is driven from or near the river on to the course of the lode which is now being worked; to do this would, I understand, cost at least two or three thousand rupees, and it is even then uncertain whether richer ore would be found. I presume that it is not the intention of the Government to undertake the working of this vein; we must wait therefore till some one comes forward with more capital than the man who at present rents the mine possesses, before so expensive an experiment can be undertaken.

3. From Captain Taylor's report it appears that only from 12 to 15 per cent. of metal* is obtainable from the ore, and though this quantity does and will pay the natives working in their primitive and inexpensive method, no capitalist would think of laying out money on so unpromising a speculation.

4. Captain Taylor visited some others of the localities at which copper ore has lately been discovered, but he informed me that the indications at the surface were not sufficiently favorable to induce him to make further investigations, and, the rains coming on, he was obliged to leave many places unexplored.

* Captain Taylor says the lode will yield in places 12 to 16 per cent., and it is clear from his data that he meant that percentage of *ore*, not of copper.—F. R. M.

5. I have lately seen some very rich copper ores from a mine in Nepál, situated a short distance from this, where in some of the veins the pure metal is found; and as the same range of hills runs through the Darjeeling territory, I feel confident that much richer lodes are to be, and will be, here met with: the very thick jungle is the great impediment to these discoveries, as during the greater part of the year the surface of the ground is invisible owing to the dense foliage which covers it.

6. The balance of the amount of Rs. 180, placed at the disposal of the Superintendent of Darjeeling for the purpose of searching for ores, has been laid out on that account, and I am glad to report that copper ore has been discovered in four other localities. In clearing the jungle around the mine, and in making the road to it passable, I was obliged to expend more money than I then had in hand, and I have now the honor to request that the Lieutenant-Governor will sanction the extra outlay, *viz.*, Rs. 48-10-9. I also beg that I may be allowed to spend Rs. 100 during the ensuing cold weather in making further search for copper ore and coal, and which search I shall be able personally to superintend.

7. I have delayed the transmission of Captain Taylor's report, in the hope that two Assistants in the Geological Survey, the Messrs. Blanford, who are daily expected, would be here and able to give their opinion on the other localities where copper ore has been discovered; but as they have not yet arrived, I have thought it best at once to despatch the report.

8. Considering that this report on the vein now worked is not of a very satisfactory nature, I have to request that the Lieutenant-Governor will allow me to rent it to the present tenant till the 30th April 1857, at the annual sum now paid by him, namely, Rs. 100; for under present circumstances I do not anticipate a higher offer.

From CAPTAIN T. TAYLOR, *to* CAPTAIN H. C. JAMES, *Officiating Superintendent, Darjeeling,—(dated* 12*th May* 1856.*)*

Having during the past month examined the copper works and the neighbouring hills agreeably to your request, I beg to hand a report thereof. These works are situated near the Manunda river and about nine miles from the plains. Only one lode, or vein, is opened and wrought on to any extent; the hill in which this lode is discovered is running at about right angles from the river, and the working is carried on about 500 feet from the base. From the great declivity of the hill I suppose the rains have washed down the superincumbent earth, showing the back or top of the lode in an easterly and westerly direction with a dip or incline or underlay north of 30° from the horizon.

2. This lode is about 2½ feet wide, with well-defined walls imbedded in gneiss or mica-schist. The component parts are chiefly quartz, iron pyrites, prian, blende chlorite, and gossan intermixed throughout with copper pyrites (some of which I

herewith send), which is frequently termed peacock-ore, from the gorgeous play of iridescent hues on the faces, angles, &c. Also, a little carbonate of copper with some spots of black copper ore. At present the lode will yield in places about 1 ton per fathom, and produce from 12 to 16 *per cent.**

3. The extent of these workings is about 80 fathoms in length and 20 fathoms in depth, or "on the course of the incline," at the furthermost point. The men have no regular system of working, but have burrowed in wherever the best spots of ore appeared. The superincumbent earth and rock is supported on props of timber 3 feet high: I never saw such holes before; but the continual sitting on their hams gives the hip and knee joints that suppleness which allows them to work in low places with ease.

4. The character of the lode throughout indicates that good deposits may be found at a greater depth; it much resembles many productive lodes I have seen in Cornwall,† especially the Caradon lodes near Liskeord, with the exception of the underlie, which I attribute to the great declivity of the hill, and no doubt it will be found greater as the works deepen. The average dip or inclination of the Cornish lodes is about 55° or 60° from the horizon; but frequently reckoned from the vertical as 2 or 3 feet in one fathom.

5. I have traced this lode for a considerable distance. At one point about four or five miles *west*, it was formerly worked on to a small extent, and some ore smelted. The matrix is a little harder. The component parts as aforedescribed, producing some good stones of ore, are, I think, of a little richer quality. I have also found three other lodes, only one showing any good indications at the surface, which is about six miles south-east from the present workings: I opened on it a little, and broke some stones containing good copper pyrites; but the immense jungle is the great impediment to making a minute investigation. In visiting the coal locality, which is near the plains on the Manunda river, I found three small veins imbedded in a compact sandstone, two of which are within a space of 40 feet. The river had undermined a large hill causing a portion to fall, thereby showing a section 100 feet in height and length. I do not put much stress on these small beds of coals, but others of importance may exist. The place is densely covered with jungle, but boring may be resorted to during the dry season. Finding coals would be essential for smelting purposes, transporting the ore would be ruinous. The Manunda river is by no means navigable.

6. Their present mode of dressing or cleaning, smelting, &c., is rude in the extreme. The first part of their process is to break or crush down the ore on a large stone, which serves for an anvil, and a stick attached to another stone for a hammer or

---

* Equal to 4 to 5½ per cent. of copper.—F. R. M.

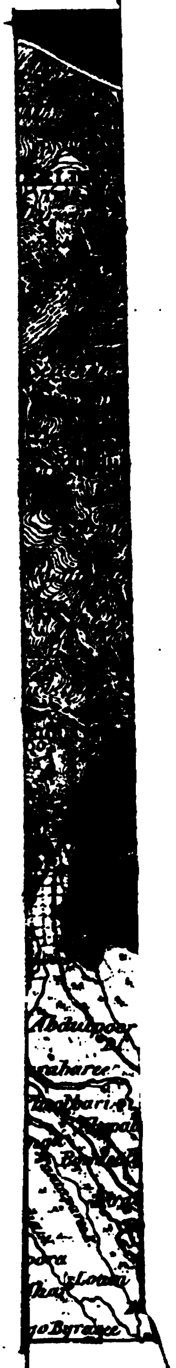
† No trustworthy comparison can be drawn between metalliferous *beds* of rock and true lodes like those in Cornwall.—F. R. M.

sledge. When so reduced that the whole would pass through what we term "a three-hole," or a sieve having nine holes in a square inch, they carry it to a strake, or small incline, made with planks about 8 feet long 1½ feet wide, having two sides and head-boards; and then wash off a great part of the impurities, which constitutes their dressing department. The produce they make of the copper ore is about 10 *per cent.* They then take the cleaned ore and put it with charcoal into a furnace, and two men keep up a continual blast until the whole is melted to a regal or lump.

2ndly.—They bruise down the lump and mix it with cow-dung, then put it in a slow fire for two days; and for refining they again put it in the furnace with more cow-dung and charcoal, and give it a strong heat until the whole is smelted or converted to a fluid, the copper, being the heaviest, settles to the bottom. They work the pure copper into cooking utensils, which they sell at about one rupee per seer.

7. Their mining operations from the first to the last stands open to great improvement, instead of working in the side of the hill as they now are, with the disadvantage of the lode underlaying in the hill, and, if I may be allowed the term, pulling the ore out "by the hair of the head."

I should recommend a level to be driven from or near the river on the course of the lode, which would not only gain a good back or top, but prove to a fair depth the intrinsic worth of the lode. Generally speaking, the copper lodes are found the most productive, from 30 to 70 fathoms below the surface; and, as it cannot be expected that one yellow copper ore lode of 2 or 3 feet wide can yield ore enough to compensate any adventure for the outlay required in India, in fact such instances are rare in England. Therefore I should recommend levels to be driven to intersect other lodes; points for driving could with little difficulty be marked out with bearings during the dry season. As to the machinery required, it would depend greatly on the condition the *ore* would be found in, also whether above or below the adit level; but at all seasons of the year there is ample water power to work all machinery required. A crushing mill from 20 to 24 in *diameter* would be absolutely necessary. If coals can be procured for smelting purposes, charcoal would be of but little moment. I suppose with coals it would take fifteen parts to produce one part metal, allowing the ore to produce 15 *per cent.* Then I should judge from the copper produced and indications of the lode opened, as well as from the general appearance of the neighbouring hills, that such explorations would in time prove the district to be a dividend-paying mining locality.



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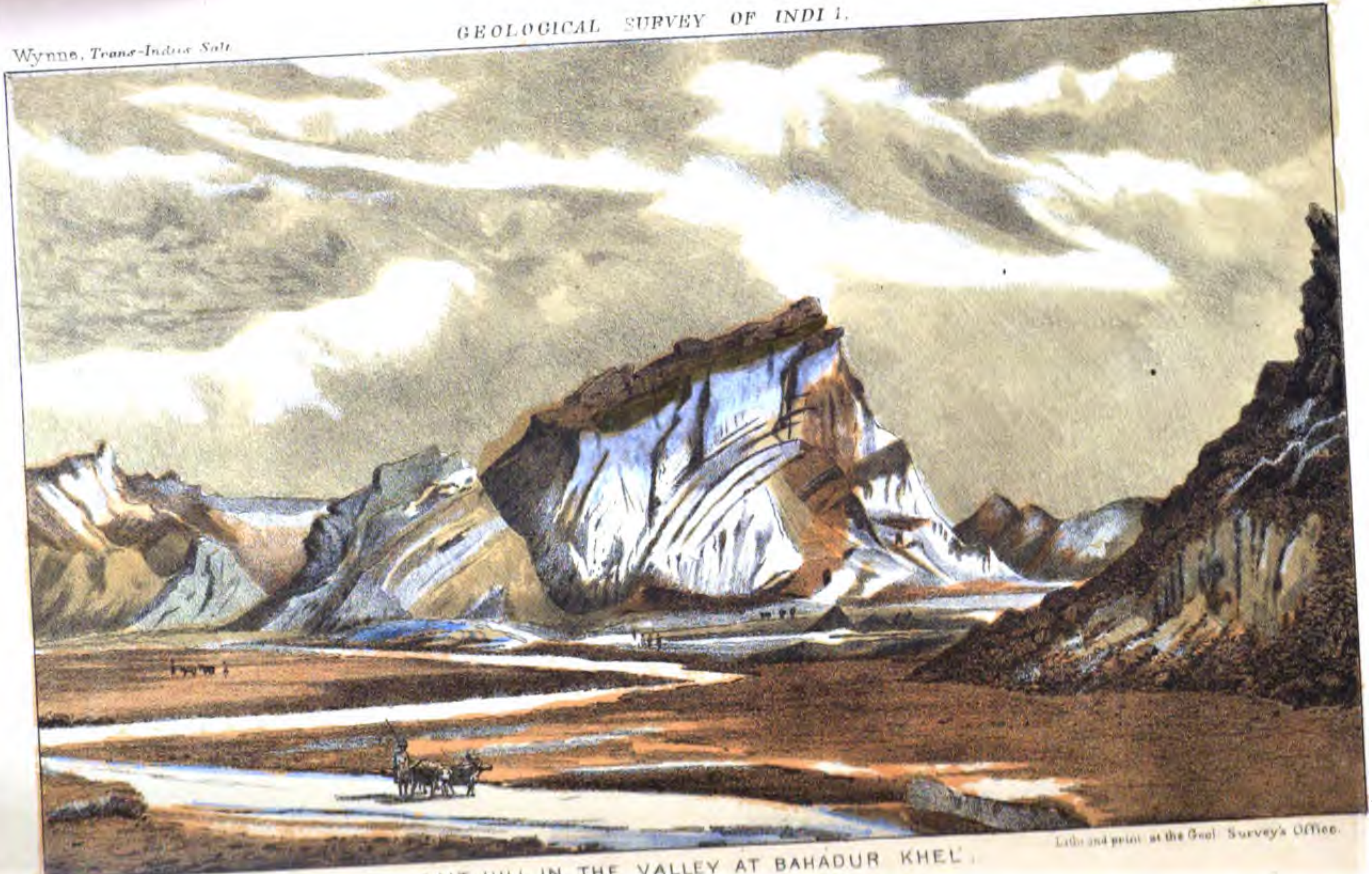

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SALT HILL IN THE VALLEY AT BAHADUR KHEL.

([illegible] of Salt [illegible] Feet High.)

J. Schaumburg, lith.

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

VOL. XI, PT. 2.

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UNDER THE DIRECTION OF

THOMAS OLDHAM, LL.D.,

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of the Roy. Geol. Soc. of Cornwall; of the Soc. Imp. de Natur.
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Map of the district from sheet 3 of the Northern Trans-Indus Frontier Survey, by Colonel Walker, R. E., Superintendent, Great Trigonometrical Survey.

PLATE A.—Frontispiece—View in Bahádur Khél Salt Valley—by A. B. W.

The whole floor of the valley, as well as the hill in the centre, which is 200 feet high, is of rock salt, except the small gypseous capping on the hill.

SECTIONS AND FIGURES.

PART I.

PART II.

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INTRODUCTION.

At the desire of Government, and under direct orders from the Superintendent of the Geological Survey of India, the Trans-Indus Salt Region was visited, and the country mapped during the working season 1873-74.

It had been represented that the map available was hardly adequate for the purpose of a detailed geological survey, but as no prospect appeared of obtaining one more suitable, shift had to be made with a MS. skeleton copy of part of the northern Trans-Indus Frontier Survey (dated 1852-53) by Lieutenant (now Colonel) J. T. Walker, Bombay Royal Engineers, published on the scale of two miles to an inch. A geologically coloured copy of the part used is appended.

Large portions of the original map are professedly unsurveyed, and its precision was not found sufficient to enable points to be closely fixed by prismatic compass bearings; for general marching purposes it answered admirably, and some of the larger stratigraphical features even were recognisable upon it, but the hill ranges are roughly shown, and the scale is far too small to admit of minute delineation of the geological boundaries, where these are complex. Indeed generally the structure of the

country has been approximately recorded with a degree of accuracy greatly depending upon the limited means at command.

In consequence of some uncertainty as to the kind of information Government wished to obtain, and in order to furnish more comprehensive details, the assistance of Dr. Warth, of the Inland Customs Department (Deputy Collector in charge of the Mayo Mines at the Salt Range), was applied for from the conviction that his special experience of salt mines and mining in England, Germany and India, as well as his practical knowledge of the Cis-Indian salt, would aid in obtaining a better acquaintance with the salt deposits of this region, while in considering them from an economic point of view his services would prove highly advantageous.

Permission was given in compliance with this application, but Dr. Warth's duties at the Mayo Mines detained him till the examination of the ground was considerably advanced; however, by making double marches he was enabled to visit the important and largest exposure at Bahádur Khél, and subsequently to join in the inspection of a large number of the other salt localities.

A rapid reconnaissance across a part of this Kohát district by my colleague, Dr. Waagen, and myself in the year 1872 had led us to doubt the identity of the two salt series lying, mainly, one on either side of the river Indus. In the hope of clearing up this point, some time, previous to Dr. Warth's arrival, was devoted to visiting the old and unused salt localities and exposures from Láchee (Láchí) to Manzullí on both sides of the upper part of the valley of the Teeree Towey (Tírí Tauí) river; the geology of the ground being mapped *en route*. After this the Bahádur Khél and other western localities were examined, and then operations were carried eastward, until temporarily interrupted by a heavy fall of snow at Sundá Kullá Khél on New Year's Day, 1874. When the weather permitted work was continued in an easterly direction towards the Indus. In no part of the district thus traversed has anything been found leading to the abandonment of previous suspicions, and

although the age of the salt cannot be closely fixed for want of certainty as to the underlying strata, there is much to be recorded indicating that it is contemporaneous with the basal portion of the 'Subáthu' nummulitic series, and thus separated by many intervening geological periods from the ancient silurian or pre-silurian salt of the Salt Range.

The obscurity in which the origin of rock-salt masses is involved appears to have been felt by our most distinguished geological authors, and to have given rise to much diversity of opinion and theory as to the natural conditions conducive to the formation of this mineral. This is the more embarrassing, since it is one neither so rare nor so limited, as to exposure, that some satisfactory conclusions on the subject of its formation might not have been expected to result from the development of geological science. As to quantity, one German author (Karsten) places it after sulphur among the principal minerals formed in the crust of the earth, and other distinguished geologists (Sterry Hunt and David Forbes)* assign to it and its components a prominent place in the chemistry of the primeval world.

In the Kohát district occur what may be ranked among the largest exposures of rock-salt known to exist upon the globe, and while engaged upon the geology of such a region, attention was often attracted to the probable past, as well as the actual present, physical relations of the saline deposits. The record of the latter may throw no additional light upon the origin of the local salt-rock, for its general characteristics seem to be much the same as those of other salt deposits, if the size and purity of the great accumulations here be excepted. But the collection of observations is a necessary preliminary to accessions of knowledge upon obscure points, while it also affords the only test by which the correctness of conclusions can be tried.

Before proceeding, cordial acknowledgments are due for liberal assistance promptly rendered by Captain Cavagnari, Deputy Commis-

* Geological Magazine, Vol. IV, pp. 357 and 433, &c.

sioner, and R. Udney, Esq., Assistant Commissioner of Kohát; also to Nawab Sir Khwajah Mahomed Khán, Khattak, K.C.S.I., of Teri, in whose country the salt is situated, and for the aid afforded under order of the Deputy Commissioner by Alliár Khán, the Superintendent of the so-called mines.

The spelling of the names of places in the following pages has presented the usual difficulty, enhanced by the addition of the official mode. This would often differ so much from the names upon the map as to create confusion, so that the spelling of the latter has been retained, the official form being added wherever the difference is considerable.

A. B. WYNNE.

1.—PREVIOUSLY PUBLISHED OR WRITTEN INFORMATION.

The previously published geological information concerning the Trans-Indus Salt Region to which we could refer was very limited in amount. Nor is it likely that any such exists regarding a district so comparatively inaccessible of sufficient importance to influence the conclusions arrived at from independent observation on the ground.

Burnes.—A paper by Lieutenant A. Burnes, subsequently Sir A. Burnes of the Bombay Army, in the first volume of the Journal of the Asiatic Society, Bengal, refers to the Trans-Indus Salt Region. The author speaks of "a range of hills springing from the roots of the white mountain (Saféd Koh)" as part of the high lands of Kabul: this he describes as crossing the Indus at Harabagh (evidently a misprint for Kálábágh), and says it formerly figured in maps under the name of 'Jood,' but that it had received the more appropriate denomination of the Salt Range from the extensive deposits of rock-salt which it contained. He then proceeds to describe the Salt Range proper, or Cis-Indus, and its mines near Pind Dádun Khán, but makes no further allusion to the Trans-Indus workings.

At the time when this paper was written, the Punjab was not a British possession, and the Kohát Salt Region probably formed a part of Afghánístán or the border country. The author may have observed hills or mountains all the way from the Saféd Koh to the 'Hydaspes,' calling the Jhilam river by its old name, but modern geographers would perhaps hardly apply the word range as he does to several long groups of elevations parallel and otherwise, but having no such general and definite direction as might be inferred from his description. The proper continuation of the Salt Range appears to pass sinuously southward of the whole of the Kohát salt-bearing area.

Fleming.—Dr. Fleming, in one of his letters addressed to Sir Roderick J. Murchison, and published in the Journal of the Geological

Society of London,* makes one of his few references to the salt of this district. He differs altogether from Major Vicary in thinking the Salt Range salt connected with the tertiaries of Pind Dádun Khán, &c., (though what these may be, seeing that place is far removed from the last exposures of the tertiary beds, is somewhat doubtful), but he thinks "it probable that the Trans-Indus salt is found in similar strata."

We are not aware on what grounds this probability is based by Dr. Fleming, but if it be from personal observation, his opinion on the subject should carry weight, as he was so well acquainted with the saline series of the Salt Range.

Karsten.—The salt mines of the Kohát district are probably those referred to by Dr. C. I. B. Karsten as near (!) the Sufêd Koh, in his voluminous *Lehrbuch der Salinenkunde* published at Berlin in 1846, (Vol. 1, p. 677). He describes the salt deposits as belonging to and forming a part of the Indian Salt Range, following apparently the paper by Burnes already noticed, an opinion which cannot be supported here.

In this volume containing so much information about the salt mines of all countries, there is an allusion to the Red Indians of North America perceiving the association of gypsum with rock-salt and thinking one a decomposed form of the other rock. It is curious to observe that the Patháns of the Kohát district also notice the recurrence of these two minerals together, and have been heard to call the salt of their country *Speenkí ka bhaí, i. e.*, brother of gypsum.

Fleming.—Dr. Fleming, in his valuable reports on the (Cis-Indus) Salt Range (Journal, Asiatic Society, Bengal, Vol. XVII, p. 500, Nov. 1848; also Vol. XXII), makes but slight allusion to the Kohát salt, thinking it to be probably the same as that of the Salt Range, but does

* Quar. Jour., Geol. Soc., Lond., Vol. ix, p. 189 (1853).

On the Salt Range of the Punjab—By A. Fleming, E. I. C., Assistant Surgeon, 4th Punjab Cavalry. Abstract of letters addressed to Sir R. Murchison. Read April 7, 1852, 1st letter from Murree, May 29, 1851; 2nd from Kutta Salt Range, July 16, 1852; 3rd, with specimens, &c., from Pind Dádun Khán, March 30th, 1852.

not give the reasons for his opinion, which, had so accurate an observer seen the ground, would perhaps have been different.

Oldham.—Dr. Oldham, Superintendent of the Geological Survey, paid a hasty visit to the district in 1864, and in his memorandum to Government on the Salt Range and parts of Bánnú and Kohát districts, mentioned the leading features of the quarries and the salt trade. The paper was not, however, intended to extend to the geological structure of the country or place of the salt series, and it will be seen from the following pages that the system in vogue then has progressed little towards improvement as regards the manner of working within the nine succeeding years.

Verchere.—Dr. Albert Verchere, in his paper on the geology of Kashmere, the Western Himalaya and Afghán mountains, likewise in the Journal of the Asiatic Society (Nos. 2 and 3, 1866, and 1, 2, 3, 1867), mentions some of the Trans-Indus salt localities with more reference to the geological age of the associated rocks. His description, however, of the Bahádur Khél exposure, while in one or two points correct, is likely to mislead. The thickness of the salt is *vastly* more than 50 feet. The red marl (*i. e.*, red clay zone) he misplaces below the gypsum; the dark brown sandstone at the base of the nummulitic rocks may belong to the red group, otherwise it is absent here, and although the place was searched for anything to represent the jurassic rocks coloured there upon his map, nummulitic limestones only were seen, and every section in the neighbourhood increased the conviction that the salt and gypsum series was directly succeeded by the nummulitic rocks, if not a part thereof.

Another, a manuscript "note on the geological formation of hills in the district of Bánnú and its neighbourhood" (1869 by the same author) has been met with.

In this there is a more extended reference to the part of the Kohát district under notice, but the rocks are mentioned (not always correctly) as if from the notes of a very occasional observer. Thus one would be led to infer that there were no nummulitic rocks between Láchee (Láchí) and Bahádur Khél, and that red marls of triassic age with small lenti-

cular beds of salt occur near the bed of the Teeree Towey (Tírí Taui) river, neither of which statements appears to be supported by facts.

The description of the section in the Soordag Towey (Súrdág Taui) or Algud (that is to say, the Kurshru Algad) near Baliádur Khél is anything but correct. The red zone which will be found described in the following pages is mistaken apparently for the red gypseous marl of the Salt Range and is called Trias! while a "thin bed of jurassic limestone" is stated to underlie a thin bed of nummulitic limestone. The short description of the section given by the author will be found to differ materially from the measured one at the same place detailed below. Káffir Kôt crags are correctly stated, however, to be of conglomerate, though whether miocene or not is undecided, and the same rocks appear to extend, as described, thence to the Koorum, but "the wall of hills" north of Bánnú valley does not appear to have the steady north-west dip attributed to it, but rather to possess undulating inclinations, forming part of a general synclinal arrangement.

Balfour's Cyclopædia of India.—In this work there are references to the Kohát district, to the neighbourhood of Kohát containing numerous mines of different metals, of which "*Soná makhí*" (iron pyrites) and "*Pital makhi*" (? what) only are mentioned. A high range of neighbouring hills is said to abound with mines of coal; fluid bitumen (petroleum ?), and momya (mumia) are stated to occur, and that the naphtha is in common use by the natives for lamps is asserted.

The authorities referred to for these highly exaggerated statements regarding the metallic and mineral wealth of the district are 'Mohun Lal's Travels, p. 358. Sch. Ad. Rec. of G. of I., No. ii,' (? Adolphe Schlagintweit, Records of Government of India), 'Masson's Journey, Vol. I, pp. 114 to 117, and Cunningham's History of the Síkhs, pp. 6, 7.' All efforts to trace these writings of Schlagintweit, if our reading be correct, have failed. Mohun Lal's travels have been thought open to doubt as to accuracy, and Cunningham's History of the Síkhs* has furnished no geological matter.

* Information kindly supplied by the Hon'ble R. E. Egerton, Financial Commissioner of the Punjab.

Other sources.—Besides the above, there are doubtless other published sources of information, but even if accessible, it is unlikely that they would treat at any length of the geological structure of the country, or its mineral resources.

Mr. Carne, Collector of Salt Customs,* 1850.—A paper or report on these Trans-Indus Salt Quarries, &c., by Mr. Carne (1850) is referred to by Captain Plowden in his memorandum, and also quoted in Colonel Macgregor's Gazetteer of the Frontier.† The original paper was unfortunately not within reach to refer to, but appears to have been a tolerably accurate notice of some of the localities then worked; with an extract from a report by Mr. P. Melville, Secretary to the Punjab Government, regarding the management of the 'mines' under Sikh rule, when they were farmed to the Khán of Teeree (Tírí) for Rs. 6,000 per annum, a further revenue being derived by the imposition of various export duties.

Mr. Carne's description of the mode of working closely agrees with that by Dr. Warth given in the appendix hereafter, but he mentions the salt of a mine near Shukkurdurra (Shukardarra), of which the name is not given (it may possibly have been either Nandrukkí or in the Loon Nallah), as being "striped red and gray salt," associated respectively with marls of the same colour, whence he inferred a passage from the Cis-Indus red salt to the gray Trans-Indus salt. He evidently regarded the salt of both regions as the same, thinking that of this district "perhaps a little sweeter."

No such alternation as Mr. Carne describes of red salt underlying red marl or clay, and gray salt underlying marl of the same colour, has since been met with or observed at the places named above or in any other part of the district. As Mr. Carne speaks of the gypsum of Spina as chalk, his geological observation may not have been very close, or he may have mistaken detrital accumulations for rock *in situ.*

* Mr. Carne was murdered and is buried at Hurreepoor (Haripur) in Hazara, one march from Hasan Abdál.

† Information from Acting Secretary to Government, Punjab.

The Hon'ble R. E. Egerton, 1870.—Access has also been obtained to a MS. note by the Hon'ble R. E. Egerton, Financial Commissioner in the Punjab, regarding the salt of this region, dated December, 1870. In this the principal points of information, the names of some of the chief localities, prices, weights, and size of 'tubbis' are briefly mentioned, and some remarks made as to the duty charged beyond the Koorum (Kúram) river, the conditions as to trade, and the management of sales.

J. A. E. Miller, Esq., 1870.—A short note attached to this paper by the Secretary to the Financial Commissioner, dated also December 1870, gives a slight idea of the position of the salt excavations, mentions the five which are being worked, what tribes were permitted to take salt from each, and the rates of sales, also that the cost of excavation varied.

Captain Plowden, 1872.—A MS. memorandum (without its annexed map) on the subject of the salt resources of the Kohát district by Captain Plowden of the Punjab Commission was submitted for information by the Deputy Commissioner of Kohát. This is an ample and valuable record of the history of the so-called salt mines, of the method of working them, and the revenue derived therefrom, as well as numerous particulars relating to the fiscal statistics of the salt. It will be necessary hereafter in considering the economic aspect of the salt quarries to refer again to this memorandum containing much information, which it is to be regretted is not obtainable in a published form.

Other MSS.—Besides the MS. paper by Dr. Verchere previously mentioned, seventeen letters of various dates, and other papers, including a *prècis* by E. O'Brien, Esq., (Acting Secretary to the Financial Commissioner), of records relating to the salt mines of Kohát have also been perused; none of these contain any geological matter; they refer generally to fiscal affairs, and were within reach of Captain Plowden when drawing up his exhaustive memorandum upon these subjects, the history of, and general information regarding, the Trans-Indus Salt Quarries.

2.—Physical Geography and Geology.

It is as well to mention here that the Trans-Indus salt field or region under notice, does not include the salt seen in the Lún (Loon) Nallah northwards from Kálá-bágh, on the same western or right bank of the river. This Lún Nallah salt has, notwithstanding the enormously broken and disconnected state of the immediately adjacent rocks, a much more intimate connexion with the Cis-Indus salt series, of which it appears to be the natural continuation, than it has with the rock-salt lying at the nearest point some twenty miles to the northward. Lithologically the salt of the two regions differs both in colour and texture as well as in general aspect. Nor is the association of adjacent rocks the same. At Kálábágh, displaced tertiary sandstones lie on one side of the salt, palæozoic and secondary limestones, &c., on the other, these latter beds never being seen in connexion with the numerous rock exposures occupying the large Kohát, or Khattak, salt region.

Situation.

Excluding this (Lún) Nallah salt near Kálábágh, the area occupied by the Trans-Indus salt region is included within about a thousand square miles of country, extending from the British Frontier eastward to near the river Indus, and lying between Kohát and Bánnú, but nearer to the latter station, which is about eighteen miles distant in a south-westerly direction from the most southerly and westerly salt exposure at Súrdág Pass.

Boundaries.—The natural boundaries of the salt-bearing country appear to be the Kúram (Koorum) river on the west and the Indus on the east; its political limits are, however, different, the 'red line,' supposed to indicate the British Frontier, excluding a large group of the Wazíri hills Cis-Kúram crowned by the mural rocks and pinnacles of Káffir Kôt.

British influence appears to be felt in the valleys wherever the land is at all fit for cultivation, but the hill ranges, far within the British Protectorate in the dominions of Sir Khwajah Mahomed Khán, are yearly

overrun in the *zemistan* or cold season by nomadic Wazíri *Yági* (independent tribes), whose flocks and rude black tents are shifted about as their own convenience or the exhaustion of the grazing may prompt.

These people are said to pay the Chief for their temporary occupation, to which they frequently return. They are a wild, largely made, athletic, but unkempt-looking race, contemptuously spoken of by the Patháns of the country as *Jánowars* (brutes), clad in rough goats' hair garments, and encumbered by but few possessions, besides their herds, their families, and their arms. They seem harmless enough, but even the shepherd on some rugged knoll, piping his *algoza* in orthodox fashion to his flock while it feeds, wears a formidable knife, or has his matchlock by his side, and it is not considered advisable to go among them unarmed, or pass the night in their vicinity. Notwithstanding this, and that they seem to keep separate from the people of the country,—with whom Sir Khwajah said they were frequently embroiled owing to cases of cattle-lifting—they were always ready to furnish water from the large earthen slung-bottles which they carry about, or to provide tobacco and *chilam* for the Sepáhi Guard.*

Ranges.—Within the area above indicated, the ground is occupied by four principal long and narrow chains of hills or continuous ranges, some of them having a length of over fifty miles, but varying considerably in width. These ranges with summit elevations of two, three, and four thousand feet above the level of the sea have an approximate east and west bearing, but diverge here and there as much as 25° both to the north of east and of west; the divergence of one range being followed

* On some occasions when belated they offered the hospitality of their encampments pressing me to spend the night in their tents, but this was declined, as the Nawab, Sir Khwajah, seemed anxious that I should return from the hills they occupied by daylight.

The fact of these Wazíris roaming thus over the salt-bearing hills would have to be taken into consideration in any question regarding the watching and preservation of the mineral. The Salt Department officers assert that they do not now steal the salt, which, may be a consequence of its low value. For their own wants and those of their animals the very water which they drink, or which they have not to go far to find, may contain sufficient to suit their tastes. If the salt was dearer the case would probably be different.

in many cases by that of the others adjacent. They are all steep and rocky, rarely supporting any plateau-like ground, and there is hardly a ravine among the many by which their sides are furrowed that has not at least one precipitous 'bad step,' if the way is not altogether barred.

Valleys.—Between these ranges are broader valleys, the surfaces of which have a level or sometimes terraced appearance, but which are intersected by many abrupt and deep nallahs with vertical sides, or are sometimes broken by small hills taking characteristic forms from the stratification of the rocks. The largest of the depressions are those north and south of the salt region, the former a part of the Kohát Plain, the latter dividing the salt region from the lofty serrated ridges of the Shín Ghar flanking the Lowá Ghar Mountains to the south. Others lie along the sides of the Tíri Taui river or its tributaries; but one large valley traversed by this river to the east, westwards towards Bahádur Khél, sends its drainage to the southward to form an affluent of the Kúram in the Bánnú basin.

Cross Drainage.—It is a peculiarity of the district that its drainage lines preserve hardly any relation to the run of its hills. The Tíri river crosses the central chain of hills, its tributary from Ismaíl Khél crosses the Jatta hills. The streams from the north of Káffir Kôt, as well as those from the Bahádur Khél valley, all cross the Súrdág ranges, and waters from the Shín Ghar and Sakar Ghar mountains cross the range to the north by the Lákkona, Algad, and the Mittân Pass.

This conformation of the ground indicates that at the time when these streams began to run, the present valleys were all filled with tertiary sandstone and clay rocks; other features than any of those which now remain determining their courses.

General aspect of the country.—The general aspect of the country is wild, barren, and rocky, being almost bare of trees and supporting nothing worthy the name of jungle; patches of cultivation appear here and there in the valleys, but are scarcely sufficient to conceal the naked-

ness of the ground; and such is the scarcity of the food for animals that those who come long distances to the quarries for salt prefer bringing forage with them to buying it in the neighbourhood. The outline of the hills is uneven, sometimes strikingly abrupt; for instance, at the conspicuous summits of Súkáwár, Húkaní, and Qund (the widower), Húkaní east of Shakardarra, or at the curiously castellated rocks west of Bahádur Khél called Káffir Kôt—

Fig. 1. Outline sketch of summit of Káffir Kôt or Lukkai Jooni Sir.

marked upon the map as a fortress! The natives said they had no knowledge of a fort having ever stood here, and if the mural cliffs were mistaken for one, it might well have been supposed to be the work of Titans (see below).

In certain cases the serrated outlines of the hills form a feature so marked that the kind of rocks of which they are composed and the position of the stratification can be assumed with considerable certainty even from a distance, while in others the arrangement of the irregularities of the ground is not less strikingly characteristic of the stratigraphical structure of the country.

Colouring of the country.—The colouring of the ground is often vivid, whole ranges taking a green tint, not from grass, but from the local colour of the rocks with which others of a bright purple hue are

strongly contrasted. Again, in the blood-red of some zones of clay varied by the white of adjacent gypsum, and broken by pale-orange or yellowish débris, the rocks themselves afford numerous changes to diversify the colour of a country which recalls the descriptions of travellers in High Asia, and which, when brightly lighted, backed as it is by the snowy ranges of Afgháníståán, is often highly picturesque. The nummulitic limestone in the landscape has gray, whitish or orange tints, the rocks below are red, white, or gray, while the tertiary sandstones above often take a dark tint from the weather; greenish-gray, red, and purple alternations characterising the whole group.

Roads.—The ground, though rocky, presents few engineering difficulties of any magnitude to prevent the construction of roads, yet there is but one of these in the whole region, that from Kohát to Bánnú, and this, as usual in the Punjáb (excepting such roads as the Grand Trunk, the Murree, and a few others) is much out of repair.

The rocks where roads would be most likely to run are generally soft and easily cut through, while certain bands of hard limestone afford an excellent material for building or metalling, and some more earthy bands in the lower part of the limestone (not, however, noticed exactly within this part of the Kohát district) might probably furnish a valuable hydraulic cement.*

There are no wheeled conveyances in the country as a rule, but until advancing civilization might bring them into use, good bridle roads might be constructed as easily as in many other countries, and would prove specially valuable for the salt traffic which now finds its way by devious tracks over difficult passes and through defiles without the least aid from engineering science.

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* In case of any trial of these clayey limestone bands for this purpose, the stone would be found very accessible in the nallah, by which a track leads northwards to the village of Turkhobay, latitude 33°35½' north, longitude 71° 52¼' east.

Physical features.—Here as elsewhere the physical features are chiefly the result of meteoric denudation, connected as a matter of course with elevatory forces, but less strikingly here than in other places, for the irregularities of the ground depend so palpably upon the harder or softer texture of the rocks that differences of form would probably have shown themselves under erosion without much reference to the degree of elevatory force exerted; still the positions of the rocks have as usual had a governing influence in deciding the shapes which the ground has assumed. Soft sandstones, when nearly horizontal or slightly inclined, have taken the forms of, or approximate to, abruptly scarped or tabular hills—the same kind of rocks at high angles forming saw-edged ridges; while all the chief ranges owe their height and character to hard zones of nearly vertical limestone of much inferior thickness, but greater strength than the bulk of the associated rocks.

Large exposure of salt.—One physical peculiarity is the way in which the salt rock occurs in naked exposures, so much more frequently and of so much larger size than in the Cis-Indus or Salt Range proper, leading to the enquiry whether this salt has or not a different solubility (not likely to any considerable extent), or whether the humidity of the atmosphere or rainfall varies in the two regions. The salt of both regions being exceptionally pure, is liable to rapid solution by fresh water, but in the salt of this region the frequently well marked stratification is sometimes defined by a slight earthy admixture of fine gray clay, (not, however, sufficient to interfere with the value of the mineral,) and this may have an effect upon its manner of exposure in masses. It may be observed too that less care is taken to preserve the worked salt here from rain than in the Salt Range, the carrier in wet weather protecting himself with his blanket rather than his load of salt, and not seeming to regard the latter as likely to suffer much: the salt here, however, being much less highly priced than it is on the other side of the Indus, this may have an influence in making the buyers careless.

Rainfall.—The average annual rainfall for the past ten years at the stations nearest to the two salt-bearing tracts has been as follows:—*

Frontier.		*Salt Range.*	
Bánnú ...	... 11·26 inches.	Shahpúr	... 15·55 inches.
Kohát ...	... 17·12 inches.	Jhílam	... 24·24 inches.
Average	... 14·19 inches.	Average	... 19·895 inches.

(The returns at Ráwál Pindí are only recorded for the past seven years, giving an average of 19·58 inches).

From these figures it will be seen that more rain falls in the Jhílam and Kohát neighbourhoods than in the others, but if Bánnú and Shahpúr be taken as the two nearest stations, respectively, to these different salt regions, there appears to be an excess in the Cis-Indus rainfall of about three inches yearly, which may have some influence in concealing or removing the salt there more than in this region.

Meteoric denudation leaves marked traces upon some of the rocks of this district, particularly those of chemical origin,—the limestones, gypsum and salt; the action of the salt-charged water from the hills upon the soft sandstone generally occupying outer or lower situations is also powerful. Many of the saline streams cut flat rocky bottoms from the beds, no matter in what position their stratification rests, and the stone at the sides of these, liable to alternate saturation and drying, rapidly disintegrates, crumbling to the touch.

The registers of rainfall as given do not show whether there may be a difference as to its periodic occurrence in the two places. The season during which the country was examined was one of exceptional cold and wet, rain having fallen sometimes twice in each month. Before this there was a long period without rain, and the powdery weathered portion of the softer rocks seemed only waiting to be washed away, while the whole country exhibited quantities of the white efflorescing salts,† some-

* From data supplied by the Deputy Commissioner of the District.

† Chiefly composed of sulphate of soda with a little common salt and a trace of carbonate of soda (Dr. Fleming's 1st Report, Salt Range, J. A. S., Bengal, November, 1848, p. 525). Sulphate of soda, sulphate of lime, chloride of sodium, and carbonate of soda (Dr. A. Verchere, J. A. S., Bengal, 1867, p. 40).

times here called *shór,* but known elsewhere as *kuller* or *toor*. This disappeared after rain had fallen, but was to a certain extent renewed again in the few following fine days, both on the sandstone rocks and superficial deposits.

Subterranean drainage.—It may be doubted whether all the water derived from the atmosphere over this district finds its way to the superficial streams and thence to the Indus. The steep forms of the ground would show that this must be the case most commonly, but where the superficial form is favourable, the occurrence of large crater-like pot or swallow holes, in very numerous localities, caused by dissolution of the salt, shows that under-ground channels exist. Springs of saline water at the bases of some of the ridges will be readily accounted for in this way, but the percolating water may be much in excess of any which comes again to the surface within the district. Where it may do so is very doubtful, and it seems strange that the whole drainage of so large a salt-bearing area, most of the streams in which are saline, should have so small an effect as to be unnoticeable to the taste in the waters of the Indus below this region, and but slightly so even in the larger streams of the district itself, such as the Tírí Tauí, the water of which has more frequently the predominating taste communicated by the *shór* of the country * than that of water saline from edible salt.

Physical geology.—As may have been gathered from some of the foregoing remarks, the physical geology is closely connected with the physical geography of the district. The ridges, ranges, and valleys, notwithstanding some extraordinary complexities (which will be pointed out), may be considered as long waves in the strata, many of which might not inaptly be compared in form to the breaking rollers of a heavy surf. The anticlinal portions of these waves show every sign of intense lateral pressure in north and south directions, and the forms of all have been greatly modified by erosion.

* Called *kárá paní* or kaora pani all over the country in contradistinction to *míta paní*, sweet or fresh water.

The cross drainage of the country, already alluded to, shows that these ranges and valleys, instead of merely directing the flow of the meteoric waters, as would at first appear, are themselves but the result of its powerful and long continued abrading force.

It is clear that the gaps through which the rivers now escape across these ridges must have been commenced under a very different state of things, at a time when the ridges, as such, did not exist, these and the whole of the present surface being then buried beneath the soft strata of the plains.

There would seem to have been a depression over the valley of the Tírí Tauí from an early period, in gravitating towards which the streams found it easier to deepen their former channels than to force a passage through masses of the tertiary sandstone series towards either the Indus or the Kúram. Notwithstanding this, the greatest effect of the meteoric water in reducing the general level of the country was undoubtedly produced upon these softer tertiary sandstones, &c.; the harder limestone and beds supported by it being left in relief, the present features of the ground were thus carved from the mass.

Structure of the ground.—Perhaps the easiest way to realize the structure of the ground is to follow the more open and less disturbed curves of the sandstone and argillaceous rocks occupying the valleys. These, with many minor undulations, are found forming troughs, the strata at the sides rising steadily, where not interrupted by dislocations, towards the anticlinal ridges, and re-appearing with the same general character in the valley on either side. From this it would follow that the rocks of the ridges must be older, and as these, largely, if not entirely, belonging to the same great tertiary formation, pass conformably beneath the beds of the valleys, the simple alternation of anticlinal and synclinal curvature might be expected to succeed. The case is, however, different, the strata rising steadily towards the ridges become steeper, vertical, and ultimately overthrown, so that along the sides of nearly all

the ranges, instead of finding the sandstones of the valleys regularly underlaid by older layers, they are, where not actually faulted, very commonly inverted, being inclined at strongly marked angles the wrong way, as it were, dipping towards the axes of the anticlinal ranges, and in some cases absolutely reposing for large spaces, in inverted horizontal order in such a way that the lowest rock of this portion of the series, the nummulitic limestone, has been found (just outside the limits of the district mapped) for the width of more than half a mile, forming an undulating horizontal cap, resting upon rocks which are absolutely newer than itself !*

* The section here close to Koteyne on the Kohát Tauí is so expressive of the complications of the district that it is given below. The inversion extends along the strike for more than seven miles.

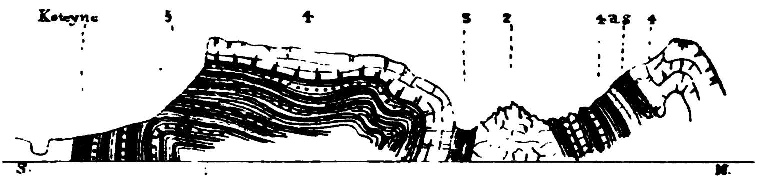

Fig. 2. Section near Koteyne on the Kohát Tauí, about one and a half miles.

2. Gypsum and gypseous series. 3. Red clay zone. 4 (a). Lower nummulitic. 4 (b). Nummulitic limestone. 5. Tertiary sandstone series.

The beds on both sides of the gypsum are not the same exactly, there being but some 25 feet of purplish red clay seen to the southward, containing a flaggy purple band, a green band with malachite stainings or films, and becoming selenitic for 4 feet near the gypsum, with thin fibrous limestone layers having cone-in-cone structure. To the north, these latter layers are much more developed, overlying a bed of greenish shale with concretionary yellow marly nodules of limestone. The cone-in-cone beds contain lenticular bituminous patches, smelling strongly of petroleum. Greenish shales are more largely present here also, and contain flaggy limestone layers, with traces of plant fragments in the clays or shales. These beds are succeeded on this side by red clays which immediately overlie the gypsum southward, but are more largely developed here. The thin and shaly lower part of the strong nummulitic limestone succeeds to the southward, overlying the more solid limestone in inverted order, this limestone itself resting upon the tertiary sandstones as shown in the sketch, though really the latter are the newest beds.

There is often a startling similarity in these inverted sections to a true ascending instead of a descending order, and were it not that within the district at the extremities of some of the anticlinal ridges the rocks are found in their proper or normal order, instances would have to be brought forward from various external localities to show that the ordinary appearance of the sections along the flanks of the hills is fallacious.

The abnormal relations described are not limited to one side of each anticlinal ridge, but seem to be, on the whole, more largely developed along their southern aspects, and though no persistent regularity of the inversion points strongly to overthrow from the north, the balance of evidence may slightly indicate a preponderance of force or thrust from that quarter.

From what has just been said, it will be seen that, at all events, in the country under notice, the great regularity and steady dip to the north-west asserted to exist in this region (Verchere, Jour. As. Soc., Bengal, 1867, p. 92,) partakes somewhat of an imaginative character.

In considering the general structure of the country we have thus a large series of sandstones and clays overlying a comparatively narrow but strong zone of nummulitic limestone, both forming open synclinal troughs, between which rise long, narrow, approximately east and westerly anticlinal ellipses, the forms of the latter being well defined by the limestone zone coinciding with the hill ranges. Down to this limestone, order, though complicated, exists, but below it disorder, and structural obscurity is the rule, the interiors of these ellipses being occupied by disturbed soft strata of clay or shale and sometimes sandstone, by quantities of gypsum and by harder amorphous or distinctly bedded masses of rock-salt.

The latter is the lowest rock known with any certainty to exist in the district. Such is the state of confusion and concealment however, that the salt might well be locally absent, or lower clays exposed.

The overlying gypsum is frequently well stratified, but its contortion and dislocation diminish its usefulness in explaining the internal

structure of the hills, though where the sections are clearest, its stratification and that of the rock-salt, which is frequently well marked, display sufficient conformity with the general anticlinal structure, however disturbed, to warrant the conclusion that a conformable sequence exists throughout from the salt up to the newest sandstones of the valleys.

System of disturbance.—The system of disturbance producing the approximately east and west anticlinals and synclinals is common to other parts of the Upper Punjab, though here complicated not alone by inversion, but by faulted dislocation, coincident with the resultant features, and usually manifest near the bases of the hills, as if original lines of weakness had initiated the curvature which occasionally relieved itself by fracture of the strata. All these lines of disturbance assume a rude parallelism, and none would appear to radiate from the centre of an area of depression.*

As a probable consequence of the relations between elevating forces and the resistance to be overcome, most, if not all, mountain chains are narrower than the plains from which they rise; so the anticlinal ridges here, regarded separately, are narrower than the valleys, still sufficient irregularity exists in this respect to suggest that the circumstance may be accidental.

The structure of the ground described can of course be most accurately known, only within reach of observations over the surface, yet it may be fairly inferred for concealed portions of the synclinals; what the forms of the denuded portions of the hills may have been it is of course difficult to conceive or restore where opposite sides of the anticlinal folds exhibit stratification which would diverge instead of approaching over their axes. The most natural supposition seems to be that the arches produced by lateral pressure were once much wider, and that either continued or repeated compression in the same direction

* Considering the faults and flexures as produced by horizontal force, the district would exemplify "a series of anticlinals and synclinals interspersed with faults." See paper by Revd. O. Fisher, Geol. Mag., 1874, p. 65.

forced the 'springs' of the arches towards each other till the upper portions under this pressure, combined with that of their own weight, assumed a position reversing the natural order of the beds, in those places where planes of dislocation did not allow of one segment of a curve becoming displaced. That the arches were complete and at one time covered by some at least of the newer sandstone strata is suggested by the cross drainage of the country and proved by the fact of considerable fragmentary portions of the latter rocks once crowning an arch, being now found located among other disordered masses within an ellipsoid of the limestone, nearly beneath their original situations.

Though the hills are not of great height, seldom exceeding 2,000 feet above the valleys where such pressure has been exerted, the structure of the ground points to a former much greater superficial area, occupied by the rocks, quite as well as if they had gone to form higher mountains.

Former greater superficial area of rocks.—If the curves of the strata be followed and even roughly restored to horizontality, it may not be too much to assume that the strata of the district under notice would before their contortion have reached in a north and south direction at least one-third further than they do at present, but the estimate can only be approximately made.

This district differs from neighbouring ones eastward in the greater variety of the rocks exposed by these convolutions of the strata; hence it may, not unreasonably, be presumed that the floor of the country, so to speak, stands generally higher (for instance, than that beneath the Potwár region), and is gradually rising perhaps in a westerly direction, thus bringing the nummulitic limestone and beds below it more within reach of the influences by which they were exposed. Either this, or a general diminution in the thickness of the overlying sandstone and clay rocks, would seem to be the case, as all the divisions of the latter recognised to the eastward are found here, and both regions are highly contorted.

III.—Geology.

The rocks of the district, of which some account is now to be given, may be classified in their natural order of superposition as follows:—

	Superficial deposits	... Diluvium, sandy river deposits, sand, recent conglomerate, and detritus.—Thickness irregular.	
Nahun? ...	Upper Tertiary Sandstone, &c....	Soft gray sandstones and clay conglomerates and boulder or pebble beds; 500 to 1,500 feet.	
	Middle Tertiary Sandstone, &c.	Gray and greenish sandstones and drab or reddish clays, with bones and fossil timber; 2,000 to 3,000 feet.	
Dugshai ...	Lower Tertiary Sandstone, &c. ... (or Murree beds.)	Harder gray and purple sandstones, bright red and purple clays, slightly calcareous and pseudo-conglomeratic bands. Bone beds occur below, also obscure plant fragments, apparently exogenous fossil timber, and in places near the base a thin layer of strongly ribbed bivalve shells, in bad state of preservation; 3,000 to 3,500 feet.	
Subathu (Eocene)	Upper Nummulitic ...	Nummulitic limestone, *Alveolina* beds more shaly, limestone with a cherty band, contain *Gastropod* sections, several *Bivalves*, &c.; 60 to 100 feet.	
	Red clay zone.	Red clay, lavender coloured at top with *Nummulites* in one locality; one or two sandstone bands near top contain fossil bone fragments; 150 to 400 feet.	Lower Nummulitic: Sandstone with *Nummulites* or thick greenish clays and limestone bands, *locally* developed *below* or *at* place of the red clay zone; 100 to 350 feet or more.

(*Observe.*)—The red clay zone is more extensive than the lower nummulitic beds.

Nummulitic (Eocene) probably.	Gypsum	White, gray, and black gypsum with bands of dark gray clay or black alum shale, gypsum, sometimes impregnated with petroleum or bitumen, alum shale generally so; series, 50 to 300 feet.
	Rock-salt	Rock-salt associated with beds of clay and sometimes earthy impurities. The upper part bituminous and base unseen, 300 to 700, or 1,200?

Rock-Salt.—Taking the rocks of the foregoing list in the order of their age, the rock-salt, being the oldest, claims attention first.

As a rock largely exposed.—This mineral occupies an important place as a rock in some parts of the district, notably in the vicinity of Bahádur Khél, where it forms high detached hills, cliffs, and naked exposures on both sides of a small stream valley (see Frontispiece) for a distance of four miles in an east and west direction, having a maximum width exceeding a quarter of a mile or 500 yards.

For four miles more to the eastward it is slightly concealed by débris or visible in many places, the sunken aspect of the ground full

of large crater-like holes proving its presence now or formerly immediately beneath, while throughout the district it is frequently exposed, generally forming precipitous outcrops within the elliptical boundaries of the nummulitic limestone.*

The exposures vary in size from the enormous one at Bahádur Khél to others of a few feet and less.

Colour and character of the salt.—The salt possesses a characteristic whitish or gray colour all over this region, its texture varying from a highly crystalline mass, the most common form, to a somewhat earthy salt intermingled with some blue or grayish finely divided clay. It often contains blotches of transparent crystalline salt (*shishi nimuk* of the natives), giving it a conglomeratic appearance and rarely minute fragments of gypsum projecting from the weathered surface of the rock.

The earthy impurities are most common in the western part of the district, where the largest exposures of salt occur, but even here only a few subordinate bands are considered unfit for working, nor is it at all certain that if such large exposures of salt occurred elsewhere, these slightly earthy bands would not be found, for in some of the eastern exposures, as at the Zaino quarries, there are also layers of salt less pure than usual.

The impurities at both ends of the district, slight though they be, would have some importance if they might be taken as any indications of original limits of the deposit in these directions.

Much the greater portion of the salt is remarkably pure, and, so far as is yet known, without a trace of contained or associated salts of another class, such as the potassa salts of greater economic value.

In the eastern parts of the district, besides the foreign matter previously noted, the uppermost portion of the salt, which is also the most impure, is frequently bituminous and sometimes slightly pyritous, this

* The various places at which rock-salt is seen or known will be mentioned in detail further on. See Part II and Appendix.

salt and the adjacent gypsum smelling strongly of petroleum. The bituminous salt prevails, however, only for a few feet from the upper surface of the deposit, though layers of bituminous or fœtid clay may be found apparently in the body of the salt-rock, through large portions of which, even when seemingly pure and crystalline, freshly broken samples have still a faint odour of naphtha or petroleum, specially observable at Jatta.*

Composition.—Specimens of the salt sent to the Laboratory of the Geological Survey of India have been examined by Mr. Tween with the following results. It appears that the better portion of the Bahádur Khél salt contains less sulphate of lime (gypsum) than the purer looking salt from Málgín, while there is but little petroleum present in any, that little being, however, often very perceptible to the senses.

Clean salt from Bahádur Khél had this composition—

Chlorine	59·52	100.
Sulphuric acid	1·5	
Lime	1·06	
Sodium	37·47	
Insoluble	·45	

The relative characters of other salt specimens from the district may be seen from the following table :—

	1	2	3	4	5
	Earthy salt from Bahádur Khél.	Good salt, bituminous, Jatta.	Upper black salt, Jatta.	Another specimen, Jatta.	Good salt, Málgín.
Loss on heating	2·2	0·4	0·8	0·2	...
Soluble matter	87·8	97·8	98·2	99·2	99·75
Insoluble	10·0	1·8	1·0	·6	·25
	100	100	100	100	100

* Rock-salt frequently contains admixtures of bitumen, clay, &c.: Cotta, "Rocks classified and described," p. 352.

On this subject Dr. Warth remarks:* "the analysis seems to justify "expectation. The natives assert the Kohát salt to be less saline to "the taste than the Cis-Indus, and it appears they are right as far as "the admixture of foreign salts is concerned; it is the latter which give "a more intensely saline taste to the rock-salt of the Cis-Indus mines." "Annexed is a comparative table of the chemical constitution of the "Kohát salt as compared with that of the Mayo Mines in this respect.

	No. 1. Kohát salt analysis above.	No. 2. Pure trade salt, Mayo Mines.	No. 3. Impure waste salt, Mayo Mines.
Insoluble matter	0·5	Trace.	1·0
Sulphate of lime	2·5	0·8	2·5
Magnesia, Calcium, Sulphates, &c.	0·0	1·7	2·5

"From this it is seen that the Kohát mineral contains no foreign salts "at all, while the best Cis-Indus salt contains almost 2 per cent. Further, "the Kohát salt contains a considerable amount of sulphate of lime and "of insoluble matter, approaching in this respect the bad salt (No. 3 above) "of the Mayo Mines. Thus the salt of Bahádur Khél is purer than "that of the Mayo Mines as regards foreign salts, and less pure as regards "insoluble matter and sulphate of lime."

Stratification.—Except where the salt is very massive and crystalline, its stratification is generally well marked, though sometimes concealed in the eastern quarries partly from the homogeneous structure and partly by the marks of the miners' picks. The slight admixture of clay at the western exposures favours the recognition of the lines of bedding which are frequently as clearly seen as in any other rock, and which also determine the local method of working.

* MS. letter, May 1874.

Thickness.—Using these bedding planes and their inclination by which to calculate the stratigraphical thickness, the maximum thickness of the salt-rock in one part of the Bahádur Khél exposure is thus found to amount to no less than 1,230 feet in round numbers. So that even making a large deduction for any slight alterations in the angles of inclination to say the salt has here a visible thickness of one thousand feet is apparently considerably within the mark, for the section giving this thickness ends both ways in salt. Even on the spot it is difficult to realise this great thickness as being true. Yet almost every bed from one side of the valley to the other might be counted, and their steep northerly dip is palpable. In mentioning the detailed features of this locality, some facts will be noticed which might strengthen the suspicion that an exaggerated appearance of their original thickness obtains, but this could only be reduced upon supposition, while, however produced, the measured thickness is a fact. Both east and west of this measured thickness, the salt has an anticlinal structure reducing its bulk, but here it is also much less exposed. In other parts of the district large thicknesses of one, two, and three hundred feet of salt beds without any alternations of unworkable salt are exposed, but in no case can it be said that the bottom of the deposit or deposits is seen.

Manner of exposure.—The salt is here associated with gypsum, as is commonly the case, the gypsum also, as in perhaps a large majority of instances where both are present, overlying the salt. This gypsum being less soluble by rain water occupies an enormously greater superficial area than the salt; and the association of the two perishable rock minerals with masses of soft gypseous and other clays within the anticlinal curves of limestone in situations subjected once to great lateral pressure, and subsequently, from their superior elevation, favouring the action of the denuding agencies (to which they are still exposed), is doubtless the reason why the rocks in the interior of the nummulitic ellipsoids present such a broken, confused, and concealed state of irregularity. Amidst obscure masses of gypsum covering and undulating over

broken hilly ground or disturbed masses of clay, the soft strata below the nummulitic limestone, or under quantities of superficial débris, deeply cut ravines sometimes expose the salt along their precipitous sides for considerable distances. In other places the local fall of a portion of the clay and débris at the head of a small nallah may allow the salt to be seen, the action of rain water sometimes tending to enlarge the exposure, sometimes to cover and conceal the salt again.

In most places it presents vertical or approximately vertical faces from the rapidity with which it yields to the action of the atmospheric water, which also cuts it into pillars, spires, and strangely fluted or systematically grooved forms, with sharp edged dividing reliefs, the hollows all leading up to points. At some favourable situations where the salt contains a percentage of clay, the slow solution of the former leaves this behind, and thus the rock-salt becomes covered by a heap of dark gray saline earth forming a coating which must ultimately act as a protection to the mineral beneath.

Joints or such divisional planes are rare in the mass, yet some strongly developed, approximately horizontal, joints have been observed, traversing salt escarpments or outcrops.

Strata that may underlie the salt unknown.—The exposures of the salt are not such as to enable any satisfactory observations to be made with regard to the possibility of some of the soft associated strata really underlying it. In but one instance did the quarrymen admit that this had ever been penetrated by their working. The statement was founded much on hearsay, and to the effect that below the salt at one of the Jatta quarries '*sheenkow,*' the ordinary gray, gypseous clay found with the gypsum had been reached. There is perhaps some probability that in so disturbed a region, if there existed any strong zone of gypsum or harder rock immediately below the lowest visible salt, it would make its appearance in one locality or another, but there being absolutely no data to limit the depth of the nearly horizontally bedded salt over a great portion of the ground in which it is seen, speculation as to what may underlie it becomes involved in the greatest uncertainty.

Continuity of the salt.—Where the ground is so much obscured, it is of course difficult to say whether soluble strata of salt may not have been entirely removed by infiltration of fresh water from certain localities, and thus it becomes impossible to determine the presence or absence of a continuous salt zone throughout the whole district. For the same reason it may not be presumed that where the mineral is elsewhere exposed, it has the same great thickness which it exhibits at Bahádur Khél, and it is quite useless to attempt to speak with certainty of the extension of the salt even from one exposure to another when these are separated by any considerable distance, the probability that it does extend being of course increased as the exposures approach each other.

Difference between this salt, that of the Salt Range, and other salts.—The differences between the general characters of the Kohát salt and that of the Salt Range are vastly more marked than the similarities to be found between them, and the associated series in the two districts. Among the former may be pointed out that the salt-rock here, wherever traceable connectedly for any distance, forms one enormous stratified deposit from top to bottom without alternation, with sharply defined bands of *(kuller)* saline clay intervening between thick zones of purer salt, as in the Salt Range. Another marked difference is that of colour, nothing resembling the red or pink Cis-Indus salt having ever been observed in this district. The bright-red gypseous marl of the Salt Range has no representative here; the clays most closely associated with the salt and gypsum being gray like the salt itself.

A deep blood-red, rather than scarlet, zone of clay in this Kohát district, entirely different from that of the Salt Range, and sometimes by its washing down discolouring the débris overlying the Kohát salt and gypsum of a reddish tinge, occupies so far a somewhat similar place, that in both cases the salt is succeeded by gypsum and the latter by a soft red zone, but in the Salt Range the red marl and gypsum are more closely associated, and may even alternate in thick zones, while the red clay here exhibits plainly a distinct horizon of its own and contains

gypsum only in thin cross veins or flaggy layers close to its junction with the mass below and in no considerable quantity. There are other distinctive characters besides to be mentioned in their proper place, and the slight similarity, so far as position, does nothing towards establishing any degree of identity between the deposits.

The whole aspect of the salt here is also different: none of the compact variety used along the Salt Range for turning into ornamental utensils occurs here, nor any furnishing the fine large cubic crystals which make up whole beds at Kálábágh. The only approach to this is in the blotches of *shíshí nimuk*, from which, when of some size, beautiful crystals may be cleaved exceeding in transparency those of the last named locality. The absence of foreign salts here, which have been found disseminated and as a separate deposit in the Salt Range salt, is another point of dissimilarity; as is also the impregnation of some of the salt here with mineral-oil, a feature not observed in that locality, though bituminous shale and clay, much associated with the gypsum here, occurs there also in one small band or deposit, with the gypsum of the Kheura gorge.

In a word, the salt deposits of the two regions are so strikingly unlike that even small samples, if not reduced to powder, are declared capable of being sworn to with confidence by those whose duty it is to prevent the Kohát salt from entering the country on the other side of the Indus.

The rock-salt of Persia lying far to the west of this district has probably no close connection with that in Kohát, as the Persian gypseous series, (and the salt) *overlies* the nummulitic formation, (Blanford, Quar. Jour. Geol. Soc., Lond., Vol. XXIX, p. 501).

The salt of the once famous island of Ormuz in the Persian Gulf is of rather uncertain, but possibly early tertiary, age, and in its manner of occurrence associated with volcanic rocks, (dolerites, trachytes), and micaceous iron, presents no analogy with that of the Kohát district.

The Mundi salt in the flanks of the outer Himáláyá is apparently different from this, both in its impure earthy composition, in having no associated gypsum, and in the age of the rocks amongst which it occurs.*

Of other rock-salt exposures in the Himáláyá, in High Asia, and the neighbourhood of the Caspian Sea mentioned in Dr. Karsten's volume, (previously alluded to), little is known, but it is worth noting his recording the frequent occurrence of petroleum with that of the latter locality, taken in connexion with the bituminous impregnation of the salt here: indeed, he seems to argue from the existence of earth-oil in Italy that rock-salt would eventually be found in the same localities.†

Age of the salt.—The attempt to fix the *precise* age of the Trans-Indus salt is beset with difficulty on account of the absence of palæontological evidence near it from which to reason. It has been stated to differ entirely in itself and its immediate associates from the Cis-Indus salt, but when the whole of the adjacent sections are examined the disparity increases. In the Salt Range the salt series itself is one of the most constant features of the geological sections. Another less constant group is the nummulitic limestone, but between these at various places are interposed silurian, carboniferous, triassic, jurassic, and cretaceous formations, besides unfossiliferous groups which have only received local or provisional names. Even where the Salt Range series is least ample,

* Mr. Medlicott's opinion that this salt is associated with the Krol (Trias?) rocks is recorded in Geological Survey Memoirs, Vol. III, pt. 2, p. 60, etc. Dr. Warth's notes made at the place coincide with this view, but Mr. Theobald, who has also visited the deposit, has seen some reason to believe that it does not belong to the older series, but is of eocene age, when it might represent that of the Kohát district. Dr. Jameson's attempt at correlation of the Mundi and Salt Range salt is open to very considerable doubt (Jour. As. Soc., Beng., Vol. xii, 1843, p. 218), and is unlikely to be correct.

† In connexion with this subject we also find that "a very rich oil-well was just discovered in Nauchaitz, Russia, on the shore of the Caspian Sea." After boring 120 feet oil was found, which flowed for 20 minutes. This was followed by a deafening noise accompanied by a slight earthquake, after which a jet of clear water, *very saline*, burst forth with great violence, running for nearly half an hour. Since then from 1,500 to 2,000 pailfulls of oil have been drawn out.—Colliery Guardian, April 7th, 1866, quoted in 'Geological Magazine,' Vol. III, p. 287. Italics ours.

the salt and gypsum lie buried below some five thick palæozoic and mesozoic groups (from the base of the nummulitic downward), forming many hundreds of feet of rocky strata. Here in the Koháť district, however, the salt and gypseous series is only separated by a band of red clays, averaging about 250 feet, from the fossiliferous basal beds of apparently the same nummulitic limestone as that of the Salt Range series. No unconformity is observable in the sections here, nor is there any established in those of the Salt Range above mentioned either.

Further than this there is not alone presumable parallelism of position from the Koháť nummulitic series downwards, but in tracing the boundaries of the formations at least one thin band of salt was found, separated by a thicker layer of dark bituminous gypsum from the mass of the salt below. Again, the gypsum was found to alternate with limestone beds or thin layers in some places, and even above the red clay zone succeeding the mass of the gypsum, strong bands of the latter were found locally interstratified with the basal portion of the nummulitic series. These alternations would appear to indicate a long period of tranquil conformable deposition extending from that during which the salt was formed up to the time of the nummulitic limestone, a period in the course of which the conditions necessary to such alternations were partially or locally recurrent.

Throughout this lower part of the Trans-Indus series the evidence of organic existence is scanty and uncertain. The fine gray clays associated with the gypsum here and there contain small fragmentary traces of grass-like plants, and a few obscure shell impressions occur in some of the accompanying limestone layers close to the gypsum; while further up in certain bands of sandstone near the top of the overlying red clay zone some broken fragments of bones have been detected, but none of these afford any grounds on which to separate the saline lower part of the series from the nummulitic rocks above.

Dr. Verchere, while leaving the age of this salt undecided, seems to have followed others in assuming that it formed a continuation of that

of the Salt Range, and on the evidence of some shelly limestone layers containing minute unrecognisable fragments, near Bahádur Khél, at the base of the nummulitic group, has apparently considered the jurassic formation to be present, and has introduced a colour to represent it on his map at that place, (paper already quoted, Jour. As. Soc., Beng., 1867, p. 26).

A careful search for jurassic beds at the locality only resulted in the discovery of some thin limestone full of broken shells, apparently of oysters, which may be those Dr. Verchere mentions. Such beds are not uncommon in other parts of the district among the inferior layers of the nummulitic limestone and underlaid by other lower beds of that formation containing *Nummulites*, &c., sometimes in abundance. Hence the introduction of an older formation than the nummulitic, on what may have been no better grounds than mistaken identity, has been avoided.

Failing the discovery of any clue leading to a more satisfactory conclusion, we are forced to draw upon probability in the effort to assign a place geologically to this Trans-Indus salt series.

To follow the vague indications of early writers, and assume that this salt series is an extension of that of the Salt Range, involves the acceptation as facts, that the salt and gypsum here are not more recent than silurian; and that in the Salt Range region now at a distance from this of say thirty* to ninety miles, (while the salt series was being gradually covered up by seven different thick palæozoic, mesozoic, and cainozoic formations) conditions here underwent little change, and nothing was deposited after the main body of the gypsum to mark the lapse of so many great geological eras except a comparatively thin accumulation of ferruginous mud!

It might be said that the Upper Punjab formations are all excessively subject to lateral change, and that scarcely one formation or group is

* At one place north of Kálábágh the salt of the Loon (Lún) nallah belonging to the Salt Range series is found within about eighteen miles of that belonging to this district at Nundrukkí.

constantly present along the whole of the Salt Range itself; the salt series at its base being one of the most constant, and therefore that the absence of many divisions of the rocks here would be no uncommon occurrence, but then it is known that only ten or fifteen miles southward of the Kohát salt tract palæozoic* and mesozoic rocks were deposited, carboniferous, jurassic, and cretaceous groups occurring in and near Chichálí pass in the Soor (Súr) ghar mountains close to the Sheen (Shín) ghar range, while one or both of the latter formations may be found among the mountains just to the north and north-west of Kohát at a distance of twenty miles from the salt region. Thus, unless the salt series of this district formed dry ground, a most extraordinary cessation of deposition which was going on around within some miles† must have taken place during the two great early and protracted periods of palæontological time. If it were dry ground however, the existence of unconformity or any traces of ancient denudation are wanting to corroborate the fact, and of all known varieties of rocks, soft clays, gypsum, and soluble salt, seem to be among those least calculated to preserve their original surface of deposition, or to resist the action of atmospheric denudation during countless ages.

There being no signs of the removal of the ancient formations from above the salt, imagination fails to suggest by what barrier deposition could have been arrested during such a lengthened time, and it is therefore well nigh impossible to believe that this salt series can be in any degree contemporaneous with that of the Cis-Indus area.

* Carboniferous both sides of Chichálí pass. Fleming's report, cit. pages 261 and 461. The jurassic and cretaceous groups were seen here by the writer and identified by Dr. Waagen, who thought some of the lower beds might possibly be triassic. The carboniferous beds do not appear in the Pass section.

† Distances to which the former expansion of ⅓rd in north and south directions may be added.

A sacred saline spring giving off inflammable gas has also been heard of near or on Mr. Medlicott's Gumber fault near Juwala Mukí, a dozen miles or so westward of Kangra, also in the tertiary rocks.

This line of enquiry suggests one improbability after another, and when these are contrasted with the appearance of parallel sequence previously described, weight may be given to the consideration that one of the minerals forming a rocky band in the salt series, namely, gypsum, is of common occurrence in varying amounts among the early tertiary rocks of Northern and Western India; for instance, in Kutch,* at Lynyán† in Sind, in the Subáthu ferruginous clays of the Simla country,‡ and along the northern side of the neighbouring Potwár plateau, extending up into the Murree hills,§ associated with red or variegated or greenish gray clays, as here. The inference from this is that some at least of the conditions by which certain of the results were produced here existed widely at the commencement of the tertiary epoch.

Besides this there are salt and petroleum springs in Burmah,|| which rise from presumably lower nummulitic rocks, and in the Nún or Lún river below Masurí a salt-spring also occurs in the tertiary series.¶

There is a strong brine spring issuing close to nummulitic limestone south of the Bakrálá ridge at Kalrá north-west of Jhílam, and some weaker brine springs are reported in the Subáthu rocks of the Potwár plateau westward by north from Fatehjung, a considerable town near the petroleum wells of Ganda, some thirty miles west of Ráwál Pindí. An analogy between the sources of the salt of these tertiary and lower tertiary brine springs, and the salt of the Kohát Frontier region, may not appear far fetched when it is remembered how great is the extension of the nummulitic formation stretching on both sides of the Himáláyá from Burmah, through the Punjab, Afghánístán, Persia, Arabia, Egypt

* Memoirs, Geological Survey, Vol. IX, pt. 1, pp. 76, 90, &c.
† Ditto ditto, Vol. VI, p. 4.
‡ Ditto ditto, Vol. III, pt. 2, p. 177.
§ Records ditto, Vol. VI, 1873, p. 61.
|| Ditto ditto, Vol. VI, 1873, p. 67.
¶ Memoirs ditto, Vol. III, pt. 2, p. 177.

and along Southern Europe to the Pyrenees (in fact from Spain to China).*

In a formation so extensive, the recognition of which is traceable to the original similarity of certain (eocene) conditions, others also may well have occurred at wide lateral intervals, and those resulting in saline accumulations at this period are known to have done so in Europe and elsewhere.

It is certainly peculiar that in such close proximity here there should be two salt series of great thickness and extent, one of not younger than silurian age, and the other associated with nummulitic rocks, a fact which is of itself suggestive of strange conditions from earliest times having affected the region of the Upper Punjab, if it does not point to an ancient local and recurring source for the mineral.

The differences pointed out in the character of the salt itself, contrasted with that of the Salt Range, together with the diversity marking the whole geological section in the two regions, and the difficulty of finding an adequate explanation of the absence here of the great overlying Salt Range series, seems sufficient to warrant the conclusion that the rock-salt deposits of these two regions are of entirely separate age: while the details given and to follow indicate that the Kohát salt, if not, as appears likely, absolutely eocene, is, at any rate, not much older than the base of the nummulitic formation.

Modern theory of the formation of rock-salt.†—This is hardly the place to dwell at length on the state of geological knowledge regarding the origin of rock-salt masses, which, it appears, may occur in any formation, from the silurian, as in the Alleghany Mountains (Abingdon), Washington Co., Virginia, United States of America,‡ and in the Punjab,

* Fisher, Geological Magazine, Vol. X, p. 257.

† The subjects referred to in this section have frequently been discussed with Dr. Warth.

‡ Karsten's work quoted; also Dana's Mineralogy.

up to the tertiary, as in Europe (among the eocene rocks of the Pyrenees, and in Germany), as well as here, or above the eocene, as in Persia.*

From the way in which the subject is treated by Lyell, Jukes, Page, and other authors, it would appear that modern writers on geology incline to the belief that rock-salt has been accumulated by the evaporation of salt-water or the sea, under favourable circumstances, some of which may be taken to mean such as would enable apparently natural consequences of the evaporation to become reversed—the deposition of sulphate of lime (gypsum), which would ordinarily be thrown down first, being delayed till precipitation of the salt was accomplished—because usually when the two rocks are present (as in this district) the gypsum seen overlies the salt.

The unascertained influence of high temperature in producing this result is alluded to by Page, who says that from the connexion of many of these deposits with axes of elevation, it is more than probable igneous action had to do with their formation. It is known that salt (chloride of sodium) is very slightly more soluble in hot water than in cold, but heat has a strong effect on the solubility of gypsum, which forms an exception in being so much less soluble in hot than in cold water, that by heating a cold aqueous solution containing the mineral the latter will become insoluble and be precipitated. Thus, heat which would not retard the solubility of salt, nor affect it much in either way, may possibly have come into operation to hásten the deposition of the gypsum and so influence its distribution.

The great difficulty as to superposition of this latter rock might be lessened if it could be supposed that mechanical destruction and recomposition of previously existing gypsum overlaid by salt had taken place. Most cases of such recomposition in stratified deposits tend to transfer the newer rock on removal to situations beneath the materials derived from the older, this being later acted upon. Instances of the

* Loftus, in Quar. Jour., Geol. Soc., Lond., Vol. XI, p. 334, &c. Blanford, *ibid*, Vol. XXIX, p. 501.

kind will be suggested by the action of rivers, by coasts and hollows which are being silted up, without the necessity of seismic disturbance, or, comparatively speaking, much difference of level. Still it appears strange if this were the case that the original order should not be more frequently met with in connexion with these deposits; and, further, if the prevalent arrangement were not the original one, it would be expected that in such great natural salt-pans as the grand Runn of Kutch, thin layers of gypsum would be found underlying the incrustation of salt, no instance of which has come to notice.

The effects of pressure and heat combined have been appealed to (Phillips) in order to account for possible conditions under which the deposition as found could have taken place; and these are indicated among other causes (such as chemical and molecular change, percolation, and magnetic currents) for metamorphism of strata as deposited into rocks like these, reasoning based on these suggestions being thought likely to lead to a solution of the problem (Page). Besides solar evaporation, gaseous emanations of solfataras and mineral springs are hinted at by Lyell as capable of connexion with these deposits; but all authorities seem united in the opinion that we require further knowledge of the chemical changes in seas where volcanic agency is in progress, of the ancient hydrography of salt regions, the chemistry and physical geography of the ocean, before "results apparently beyond the production of any known operations in nature" can be satisfactorily accounted for.

With reference to heat as one of the conditions among those just mentioned, it should be noticed that the presence of small quantities of petroleum or other hydrocarbon in the Kohát salt, if coeval, may be evidence against any temperature high enough to have driven this off.

In conformity with the apparently received solar evaporation theory, the salt or sea-water may have occupied a large evaporating basin over much of the bottom of which it had laid down a deposit of gypsum. The proportion of the latter in sea-water is greatly smaller than that of

salt, being only between ½ and 1 per cent., but the point of saturation with sulphate of lime being so much more quickly reached, gypsum might become widely spread, while the water would not part with the salt till continued evaporation had caused saturation thereby and greatly contracted its area, (in the case of sea-water the volume of the salt only representing $\frac{1}{50}$th of that of the water by which it would be deposited), the thick accumulations of this mineral indicating deeper pools left in the basin as it dried up. Thus the gypsum might occupy a much larger original area than the salt, and this area rising round the saline pools might contribute largely to the formation of a gypseous deposit capable of being mechanically removed to overlie the salt in the manner now seen.

Dr. Warth has suggested that deep brine pools such as these might be overflowed by more slightly saline or non-saline water bearing gypsum in solution or clay in suspension, which from its less specific gravity would not mix with the heavy brine below until it had reached the same point of saturation, and that in this way layers of clay or of gypsum could be deposited upon, or alternating with, bands of salt, the crystallization of which would be permanently arrested by larger accessions of fresher water.

Even supposing the formation of rock-salt possible as above supposed, the very magnitude of the enormous accumulations of exceptionally pure salt-rock in this Trans-Indus district still involves much obscurity as to their source, partly perhaps from the slightness of present knowledge as to what is taking place in the depths of many existing seas, whose waters must evaporate and be replenished by rain, and also by rivers bearing mineral matter in solution from the land; while in some oceans at least the currents are shown by recent research to be unfavourable to the separation of saturated brine or the formation of rock-salt.*

* Dr. Carpenter's lectures on ocean temperatures and oceanic circulation—Prog., Roy. Soc., 1872, Vol. XX, 535, &c., on the 'Shearwater' Scientific Researches—to Royal Institution, 1874, March 20. 'The temperature of the Atlantic'.

This may nevertheless be going on in favourable situations, as is said to be the case in a land-locked arm of the Caspian;* or, as has been suggested with regard to the Red Sea, notwithstanding that deep ocean soundings in recent years have not borne witness to the fact.

In discussing the circumstances of the salt region under notice with Dr. Warth, it appeared that if a column of sea-water may deposit $\frac{1}{50}$th of its volume of solid salt† it may be roughly calculated that to produce the two square miles of salt taken at $\frac{1}{5}$th mile thick at Bahádur Khél, a volume of sea water of the same depth and 100 square miles in area (equal to twenty cubic miles) would be required, and this should probably be evaporated to half its original bulk before deposition of salt would commence.

If the whole of the salt deposits be considered to represent a series of brine pools formed by the slow desiccation of a once continuous sea, the area within which they occur being one of about 1,000 square miles, and the salt presumably present over more than $\frac{1}{5}$th of this area, or 200 square miles, this sea may have had a depth equal to the unknown thickness of the salt deposits in most of the districts, and a superficial extent of 1,000 or 2,000 square miles according as it may have been deep or shallow, while if the rock salt be, or was once, continuous from one exposure to another over the whole area of 1,000 square miles, the extent of the depositing sea may have been from 50,000 to 100,000 square miles.

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* At Kara Bugaz (?) (*i. e.*, The Black Gulf), eastern side of the Caspian. The accumulation of the salt in this case may be gradually increasing, but it is by no means clear, so far as can be learned, that the sources of the salt supply are not traceable to the rock-salt stated by Karsten to occur extensively on the eastern borders of the Caspian rather than merely to its own waters.

† Bischof (quoted by Jukes in his Manual, p. 137,) gives saline matter in sea-water as 3·527 per cent., of which 75·786 in 100·000 is chloride of sodium. Taking sea-water to contain sixteen times as much salt as gypsum (same authority), it is curious to note the similarity of this ratio to that between the calculated thickness of the salt and gypsum in the Bahádur Khél exposure.

Anything worthy of the name of an inland sea or large lake would cover the whole of the salt-bearing country, as far as extent goes, and as the gypsum extends much beyond the salt region, while all the rocks of the district may once have had an expansion one-third greater in a north and south direction, it is probable that the saline water would have occupied or exceeded the largest area named.

This rough estimate will serve to show that, according to existing natural conditions, there is sufficient salt in a rocky form in this district to have impregnated all the waters of a considerable sized inland lake or sea. The mode of its collection into the form of solid strata of large thickness and greater or less horizontal extent, or the conditions under which the water would have disappeared by evaporation, conformably with what appears to be the most generally adopted theory, can only be surmised.

In the last paragraphs sea-water has been used to illustrate the probable formation of the salt, its composition being better known than that of the waters of many inland lakes or seas, which might give different results, but from a passage in Dr. T. Sterry Hunt's lecture on the chemistry of the primeval earth (Geological Magazine, Vol. IV, p. 364), he would seem to believe that "there has been a slow progressive change in the constitution of the ocean," so that the conditions may not now remain the same as they were when the salt was deposited.

Assuming these to have been at least similar to some extent, what special causes there may have been in operation to facilitate the formation of the rock-salt there is little or nothing to suggest. In this connexion it may be observed that the circumstances of deposition generally in the Upper Punjab seem from very early palæontological times to have been subjected to strange peculiarities of lateral limitation. The thinning out of whole formations may only mark absence of material to be deposited; in the case of sedimentary rocks, but in those of chemical origin, the depositing seas would themselves appear to have been limited or divided by land. Together with the

frequent repetition of discontinuity, there is from the lowest to the highest groups in some regions such an absence of unconformity that through the long list of periods down to tertiary times results of any violent local disturbances are unknown, these only being referable to causes connected with Himáláyán elevation and dating from the eocene age.*

In such a vast succession of comparative tranquillity (if the absence of older rocks than nummulitic could be explained), time might have been adequate and ample for the accumulations of a thickness of salt rivalling that of all the known palæozoic fossiliferous accumulations of the Salt Range and far exceeding in depth many of its separate groups, some of which might even be supposed represented in time by part of this great salt series; were it not that even after making allowance for formerly greater superficial expansion of the country, there are still no reasonable grounds for the belief in such a permanent 'Swatch of no ground,' and of no deposits existing between the points where mesozoic or more ancient deposition is known to have been taking place.

If we turn to the known natural salt pans of the present day for an illustration of the method by which such enormous deposits of rock-salt as these were accumulated, it may be strongly doubted whether the whole world affords anything approaching a parallel case likely to produce a similar result. The Runn of Kutch is a favourite example of the natural formation of salt from sea-water on a large scale, under conditions of intermittent floodings by saline water, yet the salt formed there by evaporation is only a few inches thick and not sufficient to cover the whole of its surface, while the formation (even if accompanied to some extent by re-solution) has been going on for an indefinitely vast period, but little interfered with by one of the greatest earthquakes of the present country.

* The occurrence of boulders of foreign rocks is not here contemplated. Although these occur in some of the oldest groups, they are no evidence of local disturbance, but rather of tranquillity enabling them to subside.

The Sambur Lake, another Indian example, fails also to afford a parallel to the magnitude of the salts in the case before us, and of others so little can be asserted to the contrary, that it may safely be presumed the salt-producing lacustrine or lagoon conditions of the present time are so unequal in comparison as to have no weight in supporting the idea that the causation of the frontier salt deposits was at all the same.

The structural indications of the manner of accumulation of these salt beds are few and may be briefly mentioned. The frequently perfect stratification of the salt plainly shows repeated or periodic deposition and cessation, while the occurrence of the numerous cases of oblique lamination exactly as in other rocks points to the existence of currents in the depositing water. The freedom of much of the salt from visible impurities or foreign substances testifies to the clearness of the fluid, but it would be unsafe to assert that this water was itself the only source whence the mineral was derived.

The impregnation of some of the salt with bitumen or petroleum is the only remote indication of anything organic associated with it, and the origin of this is entirely obscure. Salt-forming regions are usually lifeless; no place could well be more so than the Runn of Kutch; the description of the Dead Sea will be familiar, and at the Abyssinian salt regions, Karsten alludes to the absence of living things as enhancing the barren desolation of the dreary scene.

GYPSUM.

As a rock.—As another of the rocks of the district, the gypsum group holds an important position from the large area it occupies. Closely associated with the gypsum itself are certain thick zones of greenish, sometimes smoothly stratified, clay, often containing translucent crystalline plates or fragments of selenite which glisten on its weathered slopes; these clays have only been found to enclose impressions of small fragments of grass-like plants.

Occurring with the clays, and in places as if below the main gypsum, or both below and above it, are bands of limestone sometimes hard and compact, sometimes flaggy and transversely crossed by a fibrous crystalline structure, which more or less perfectly takes the well-known form of 'cone-in-cone.'*

Both the gypsum and associated clay have received from the natives distinguishing names, the gypsum being as well known by the name *Speenkí* as the salt by that of *Malga* (Pushtú), and the clays being called *Sheenkoura.*

Character and solubility.—The gypsum, as indicated by its Pushtú name, is very generally of a white color, showing itself plainly even on dark days at long distances among the hills, but it sometimes has a grayish hue,† more rarely variegated with deep red from decomposition of iron, and it often in its lower part passes into shaly beds, quite black, smelling strongly of petroleum; its texture varies from subcompact to more crystalline varieties.

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* Close outside the district.

† The Potwar gypsum is also white or gray, and associated with clays very similar to *Sheenkoura.*

The Sambur Lake, another Indian example, fails also to afford a parallel to the magnitude of the salts in the case before us, and of others so little can be asserted to the contrary, that it may safely be presumed the salt-producing lacustrine or lagoon conditions of the present time are so unequal in comparison as to have no weight in supporting the idea that the causation of the frontier salt deposits was at all the same.

The structural indications of the manner of accumulation of these salt beds are few and may be briefly mentioned. The frequently perfect stratification of the salt plainly shows repeated or periodic deposition and cessation, while the occurrence of the numerous cases of oblique lamination exactly as in other rocks points to the existence of currents in the depositing water. The freedom of much of the salt from visible impurities or foreign substances testifies to the clearness of the fluid, but it would be unsafe to assert that this water was itself the only source whence the mineral was derived.

The impregnation of some of the salt with bitumen or petroleum is the only remote indication of anything organic associated with it, and the origin of this is entirely obscure. Salt-forming regions are usually lifeless; no place could well be more so than the Runn of Kutch; the description of the Dead Sea will be familiar, and at the Abyssinian salt regions, Karsten alludes to the absence of living things as enhancing the barren desolation of the dreary scene.

Gypsum.

As a rock.—As another of the rocks of the district, the gypsum group holds an important position from the large area it occupies. Closely associated with the gypsum itself are certain thick zones of greenish, sometimes smoothly stratified, clay, often containing translucent crystalline plates or fragments of selenite which glisten on its weathered slopes; these clays have only been found to enclose impressions of small fragments of grass-like plants.

Occurring with the clays, and in places as if below the main gypsum, or both below and above it, are bands of limestone sometimes hard and compact, sometimes flaggy and transversely crossed by a fibrous crystalline structure, which more or less perfectly takes the well-known form of 'cone-in-cone.'*

Both the gypsum and associated clay have received from the natives distinguishing names, the gypsum being as well known by the name *Speenkí* as the salt by that of *Malga* (Pushtú), and the clays being called *Sheenkoura.*

Character and solubility.—The gypsum, as indicated by its Pushtú name, is very generally of a white color, showing itself plainly even on dark days at long distances among the hills, but it sometimes has a grayish hue,† more rarely variegated with deep red from decomposition of iron, and it often in its lower part passes into shaly beds, quite black, smelling strongly of petroleum; its texture varies from subcompact to more crystalline varieties.

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* Close outside the district.

† The Potwar gypsum is also white or gray, and associated with clays very similar to *Sheenkoura.*

Two specimens of the dark-coloured beds, associated with the gypsum, and smelling strongly of petroleum, examined at the Laboratory of the Geological Survey by Mr. Tween, gave the following results:—

	No. 1.	No. 2.
	Dark bituminous gypsous bed from Jatta Salt Quarries.	Dark bituminous shale with traces of gypsum Algad, between Muzdukkai and Spína.
Loss on heating	18·6	5·6
Soluble	35·8	89·2
Insoluble	45·6	5·2
	100·	100·

The greater part of the soluble matter in No. 2 consists of carbonate of lime.

Impurities.—As a rule, the gypsum is pure and homogeneous, the only foreign matter observable in hand specimens being some gray clay, crystals of iron pyrites, crystals of quartz, dolomite, or anhydrite in a few places, and the bituminous ingredients of the black portions.

The anhydrite just mentioned is rare, occurring in the form of very small, but beautifully clear crystals, imbedded in the lowest stratum of the gypsum just above the main mass of the salt at Saya Malgeen (Séya Málgín).

Alum shale.—Associated with the gypsum in the eastern side of the district are one or more bands of black alum shale, so charged with pyrites as to have formerly induced their being worked for sulphur, which occurs native in small quantities, the result, apparently, of chemical reaction going on at the places where the shale occurs, and from which sulphurous gases emanate. The rock, too, is frequently coated with alum to such a degree as to affect one's skin in handling it.*

* Dr. Verchere suggests that alum shale in a neighbouring district is a product of the metamorphosis of lignite, but does not describe the process (paper previously quoted, p. 27).

The broken and disturbed character of the series renders it difficult to fix the place of these alum shales with certainty or narrowly, but they probably form a band not far above the lowest layers of the gypsum. In the country lying southward and south-eastward of this district two zones of alum shales occur, one near the base of the nummulitic rocks, the other in the jurassic series; these here may be the representatives of the newest of those in the nummulitic rocks, for though the associated beds differ, the relative place beneath the mass of the nummulitic limestone is approximately the same.

Stratification.—The stratification of the gypsum is not uniformly evident; in some places the beds appear to be thick and massive, or the bedding laminæ are indistinct; in others it becomes thinly divided or flaggy, showing alternations of gray and whiter colour. The lamination is rarely parallel; more frequently it assumes complex folds, sometimes on as small a scale as may be observed in the contorted foliation of gneiss or other crystalline rock. The alternation of the gypsum with the gray clays is in places very distinct, in others most obscure, and towards the top of the main gypseous band, this frequently passes by alternation of thin layers into the red clay zone which follows. Where the soft clay has been washed from between these upper gypsum layers, as well as occasionally in other parts where the stratification is clear, distinct current or 'ripple' marks have been observed on the surfaces of the beds, indicating their having been accumulated in shallow water.

Fossils.—No organisms whatever have been found in the gypsum, and none in the associated gray clays, except the obscure grass-like fragments already mentioned, but in a limestone band near the top of the gypseous group associated with gray clays, some small and fragmentary shell impressions were detected. One seemed to be a fragment of an oyster, the others might have been anything.

Wasting.—The solubility of the gypsum by rain is plainly shown by the way in which its surface is frequently deeply fretted into minia-

ture models of hill ranges, with serrated knife-edge ridges and deeply-gullied sides, or where it is (as is not uncommon) traversed by rectangular veins of greater hardness, the interspaces between which are often eroded into perfectly flat-bottomed hollows like little salt-pans; the surrounding lips of these sometimes have no opening or depression to enable the water to drain off, so that the dissolved mineral from within can only have been removed by the wind or by overflow.

This system of rain furrows, always more or less upon the same plan, may be frequently found upon surfaces of homogeneous limestone, more frequently upon gypsum, and most largely developed upon the exposed exterior of the rock-salt.

Another result of the solubility of the gypsum is its apparently frequent recomposition or rearrangement into a rock somewhat resembling calcareous tufa. This form of the mineral or rock occupies, as a covering, much of the gypseous ground, conforming rudely to its surface even in deeply cut ravines. Such masses, on being searched, may be found to contain some decayed fragments of limestone in which are nummulites as well as pieces of other local rocks, and in the paste small crystals of dolomite and bipyramidal clear quartz may be met with. Unlike calcareous tufa, stems, leaves of plants, &c., do not appear to have been preserved by incrustation or replacement.

The gypsum not limited to one zone.—Though prevalent in great and more or less continuous masses, the gypsum cannot be said to form an unbroken sheet, its apparent discontinuity being perhaps due to dislocation or denudation, or both. Nor is it limited either above or below by any arbitrary boundary. Thus, in the Malgeen Sáya (Málgín Séya) hills a layer of salt was seen to separate a mass of dark gypsum from the rest above; in other parts of the eastern side of the district layers of limestone, or of limestone and clay, were observed near the top of the main gypsum mass; beneath a less strongly developed bed of the latter, and in about the centre of the salt region, thick bands of gypsum

occur among the basal beds of the nummulitic series. They are not, however, constant, and one was traced till it thinned out between the adjacent beds of limestone.

Thickness.—The disturbed state of the ground places much difficulty in the way of estimating the thickness of what we may call the gypseous series. In *one* section at Bahádur Khél, the gypsum has no greater thickness than 32 to 40 feet, and the gray clays are there but poorly represented. In other parts of the district one is perhaps inclined to overestimate its depth from the manner of its exposure, presence of superficial gypsum, &c., but in some cases it certainly seems to have a thickness of, or approaching to, 200 feet, while with the clays, the whole may average more than 300 feet.

Conditions of formation.—The circumstances accompanying the deposition of this series as indicated by the rocks must have differed considerably from those which obtained during the formation of the underlying salt. The clearer waters were now liable to influx of clay or mud, and again probably still and clear while the gypsum was being deposited, becoming occasionally shallow and subject to currents which left their traces, as they do now, in the form of ripple marks on sandy or muddy bottoms.

The amount of gypsum which water may dissolve is very small, not being more than 2·5 of gypsum in 1,000 parts of water, and its accumulation from aqueous solution in the present case would point to long intervals during which earthy impurities were not present in the water in any quantity, alternating in places with an opposite state of things when mud or clay was greatly in excess. The deposition of the gypsum from solution would doubtless have been hastened by accession of heat, if this could be shown to have taken place, but whence it might have been derived there is nothing to prove. The water may have been at times so shallow as to have its temperature raised by the heat of the sun, or thermal gypseous springs may have been in operation (as shown to have been the case in the Spiti valley by

Mr. Mallet),* sending forth volumes of warm water which could have floated over a denser saline liquid below (as previously observed), or it may be possible that the 'mother liquor,' after depositing the salt, may have retained a quantity of chloride of calcium, the accession to which of water impregnated with sulphate of magnesia or soda would have produced sulphate of lime, *i. e.*, gypsum.† As with respect to the salt, so in the case of the gypsum, the presence of much heat, at least since the rock became impregnated with petroleum or bitumen, does not appear probable; on the other hand, the small quantity now present may be but the residue of a larger supply already driven off. Hot springs and so-called hot springs are not unknown in the Punjab now, and if these were more frequent or more voluminous in bye-gone ages, their existence might not be incompatible with the fact that latent forces of disturbance still show themselves in the frequent earthquakes, one of which was distinctly felt at Láchí during the examination of the district.

All such views, however, infringe largely upon the regions of conjecture, for which there is generally ample room when facts are scarce.

* On the gypsum of Spiti, Mem. Geol. Surv., Ind., Vol. V, p. 151. Hot springs are also supposed to have aided in forming the gypsum of the Salt Range by Dr. Verchere,—paper previously quoted.

† Dr. Warth.

RED CLAY ZONE.

Generally present.—Overlying the gypsum there is very generally present a thick zone of deep red clay, the presence of which is often indicated by the colour of the talus at the base of the nummulitic limestone outcrops. There are, however, situations where in an exceedingly broken, disturbed, and often concealed country, this red zone does not always appear next above the gypsum, giving place to sundry gray clays, shales, or brownish sandstones at some height in which a less developed red clay band, believed to be the representative of this, occurs. Where these gray clays and sandstones are absent, as is the case over most of the district, the red zone, or its débris, is always to be found in any consecutive section of the rocks occupying its proper place.

It seldom shows its stratification well, but under favourable circumstances, bands of slightly different tint mark the bedding, or there are alternations of more sandy nature, sometimes becoming flaggy and variegated by green spots.

Similarity to other red bands in the Punjab.—Where this flaggy structure prevails the group so much resembles a red zone, believed to be of triassic age in the Eastern Salt Range, that it has been searched for the pseudomorphic crystals of salt so common there, but without success, and there is no other similarity to the Salt Range band, the rocks above and below which are always absent here. Some resemblance might be traced between the brownish sandstone and gray clay series, in some places overlying the red band here, and the olive series above the Salt Range red zone, but the comparison would not hold, for the olive series contains a few fossils, believed to be cretaceous, while the brownish sandstone and gray clays of this country are nummulitic.

But there is another set of red clays in the Upper Punjab to which this is also very similar. It is traceable at intervals wherever the Subáthu zone is found closely associated with the nummulitic limestones. The colour is much the same, and both contain sandstone or sandy alternation, differing, however, greatly in development in the

Cis- and Trans-Indus regions. The association of both of these red bands with nummulitic limestone favours the supposition of their being both of nummulitic age, though it is not sufficient to warrant the assertion that they are on exactly the same horizon.

Bone and other fossiliferous beds.—Near the top of this red clay group a single or double layer of harder rocks may frequently be observed. These are sometimes coarse purple sandstones, each seldom more than a couple or three feet thick; sometimes they are thinner, and concretionary or pisolitic hæmatitic bands, while in some localities they become thicker and conglomeratic, containing also small fragments of bones, unfortunately not likely to be of use in fixing their age. At a locality far distant from where the bones occur, some layers with *Nummulites* were also observed in these red beds not much below their junction with the overlying limestone.

These few traces of fossils are among the oldest and earliest traces of existence in the whole of the Salt Region, the few fragments in a limestone band at the top of the gypseous series being older, but neither being in a state of preservation likely to convey any information as to age, and in no other part of the red zone has any better fossil evidence been found.

Representatives, east and west.—From a passage in Dr. Verchere's paper previously alluded to,* it might be surmised that the rarely hæmatitic layers of this group are developed more largely westward in the country of the Wazírí, furnishing the Wazírí iron of commerce in these parts. In the Salt Range to the east, the only representative which can be suggested for the group is a band of red and white variegated hæmatitic clay of inconsiderable thickness, which occurs just beneath the nummulitic limestone of the range.

Thickness.—The thickness of this red clay zone varies somewhat, being seldom small, and sometimes measuring over 300 feet or even nearer to 400 feet. Two hundred and fifty feet, however, may be an

* Jour., As. Soc., Bengal, 1867, p. 20.

approximate average, but it has in places been found to measure even less than 20 feet.

Conditions.—With the deposition of this red zone things must have changed again, and locally so much that its regular succession was much obscured. The water in which it was deposited was charged no doubt with ferruginous matter, whence the colour it now assumes. The lowest layers alternate clearly with the gypsum for a short space (just a few feet); a certain amount of variety is indicated by the local presence of sandy materials, and the upper layers containing nummulitic bands; the whole group would seem to link the nummulitic and gypseous groups into one series.

Minerals.—On the horizon of the harder bands near the top of the clays, a sandy bituminous layer was observed in a stream gorge west of Muzdukkai hill. It varied from 1 to 3 feet in thickness, and seemed so saturated with mineral-oil as to increase its weight, yet this did not seem to exude. This, the pisolitic hæmatite layer, some narrow gypseous strings, and thin veins of sulphate of baryta, with some small concretions stained with green carbonate of copper, were the only minerals observed in the group.

NUMMULITIC SERIES.

Formation inconstant in the Punjab.—The nummulitic rocks of this district belonging to one of the groups of the Upper Punjab most liable to local changes—changes which are, nevertheless, insufficient to affect the recognition of the formation in different parts of the country, the formation may be said to present itself under three more or less separate aspects, namely, those of the Salt Range type, the Subáthu type, and the hill nummulitic type.

Here the two former of these types seem to be united so that the local groups may be looked upon as exhibiting an unusually extensive development of the Subáthu character blended with some of the features characteristic of the Salt Range nummulitic zone.

Local inconstancy.—As the general features of the nummulitic rocks of the country are versatile, so, even within the limits of this salt-bearing region, the sections across it vary in different places, from the entire absence of this group by thinning out, to its enhanced thickness by including beds not usually present. Where thinning out of the limestones takes place, the upper portions are always the first to disappear; and the chief additions to the whole group are a mass of shales and sometimes of light coloured sandstones, which locally come in below the main limestone zone.

General succession.—The inversions of the adjacent strata are most prominently marked by the occurrence of these limestone beds, which, as it were, form a key to the complicated stratigraphy of the hills, being most extensively distributed, while the clays or soft shales and sandstones are collected into a group by themselves at the base of the series, rather than distributed by alternation through it, though occasional bands of shale do occur also in the latter way. The following may be given as a diagramatic table of all that is certain to belong to the nummulitic limestone group in this district, there being, however, reason to suppose that this eocene series may include all the rocks below the limestone

itself. It does not follow that the whole of the rocks in the following list should be present at any one place :—

Nummulitic series.

8. Variegated yellowish, light-gray yellowish and pinkish, or gray or whitish limestone or marble, lumpy and marly beds below with *Nummulites*, *Alveolina* throughout.
7. Gray limestone with *Alveolina*.
6. Gray limestone, rather darker, containing small *Nummulites*.
5. Thick and thin-bedded regular limestone, few fossils, some of the beds semi-oolitic.
4. Earthy gray limestone and greenish shale with *Nummulites*.
3. Dark cherty limestone with few fossils, a few feet only.
2. Gray limestones and gray or greenish clays, thin-bedded layers, *alveolina* bands occasionally, or layers with *Nummulites*. On or about this horizon, brownish sparkling sandstones and gray or greenish-olive clays, with bands of red or purple clay, are locally present in north-westerly sections ; the sandstones being in places conglomeratic.
1. Greenish clays sometimes gypseous or containing plates of selenite below, sometimes having calcareous *nummulitic* layers.

Where the groups 1 and 2 of this list are present, the red zone so prominent elsewhere loses its character and place as next overlying the gypseous series, pale brownish sandstones and greenish clays taking an intermediate position between the gypsum and the now sub-divided and thinner representative of the deep red or purple clay zone. The bands most retaining the general appearance of the latter are usually those nearest to the stronger limestones above, and these red bands are certainly interposed between or intercalated among beds containing *Nummulites*, thus giving another clue to the fact of the red zone itself and the gypsum into which it passes below by sudden alternation—all belonging to one early eocene period.

In order to show the difference between the ordinary junctions of the red clay zone and nummulitic limestone and the obscure passage downwards from the latter where the sandy and shaly lower nummulitic beds are present, the sections south-west of Amon Kót and Shárki,

(fig. 17) and (fig. 18), may be compared with those on the Kúrshru Algud near Bahádur Khél, (fig. 36), and near Gúrúza, (fig. 42.)

Sandstone bands similar to tertiary sandstones.—Apparently about the place of No. 7 in the foregoing list, there are sometimes a few beds of purple sandstone and clay present, very much resembling those of the succeeding tertiary sandstone group. In several instances such bands, apparently within the limestone group, have been found to belong to the series above misplaced by dislocation, or brought in by both curvature and faulting, but in other cases, from the apparent regularity with which these bands seem to be included, it would be unsafe to assume that they are never really intercalated with the limestones.

Concealment by débris.—If the nummulitic limestone affords a key to the structure of the country, on the other hand, the quantity of hard débris which it forms overshooting the slopes of the hills mostly on the outcrop side, adds greatly to the difficulty of seeing the complete succession of the rocks, many miles of hill side being covered, and the rock beneath almost entirely concealed by this débris, from the limestone of the ridge to the foot of the declivity, and frequently in situations where only a few projections of gypsum serve to indicate the interest of sections which the ground might otherwise afford.

Varieties in succession.—The lower rocks are gray shales or clays with occasional calcareous bands. They take a greenish olive colour where weathered, and are not unfrequently gypseous, being then undistinguishable from the '*Sheenkoura*' beds of the gypsum series below. In these clays or shales fossils are often rare for a depth of very many feet, but become suddenly abundant in thin or flaggy layers of limestone largely made up of *Nummulites*. Thicker beds of limestone occur irregularly higher up containing numerous fragments of oyster-like shells and sometimes a few corals.

At about this position the greater portion of the shales of some localities underlie strong brown sandstones of soft texture and light colour, in parts conglomeratic and enclosing nummulitic pebbles as well

as nummulites in the paste, thus showing that even at an early date the rocks of the group were irregularly distributed, and that limestones were suffering degradation, while other beds of the same period were being deposited, but at what distance from the former we have no evidence to prove.*

These sandstone beds have rather a local distribution, and appear to be developed with, or as a part of, the clays or shales just mentioned.

So situated as to overlie the clays, sandstones, and limestones described is a zone of very dark-coloured limestone with rugged bands of white chert. Fossils are rare in the band, except some few sections of large, spiral shells and even less frequently a discoid gastropod having somewhat the form of *Planorbis.*

Above these are gray, earthy, nummulitic limestones with some bands of greenish shale, followed by thick and thin-bedded parallel limestone

* The presence of such pebbles as these is always rather difficult to account for where no absolute unconformity is known to occur. At first sight they might seem conclusive evidence of the existence of an older limestone, its erosion, transport of its fragments, and their deposition elsewhere. Limestones, especially these with nummulites, have been often considered pelagic, the nummulites being supposed deep sea organisms, but that the waters in which nummulites lived need not in all cases have been so very deep may be considered proved by the manner of occurrence of the nummulitic beds—sometimes sandstones—of the Subáthu group, exterior to the hill limestones lying northward from Ráwál Pindí.

If some of the limestones could be supposed capable of consolidation near coasts becoming thus liable to destruction by wave action the mystery might be solved, for I have seen a sandy calcareous rock on the Indian shore of the Arabian Sea becoming consolidated between high and low watermark, the recent shells in which were converted into white limestone. Fragments of this rock, broken or worn down by the surf, would be included in the sandy shore deposits containing the same shells, and yet be no evidence of unconformity which, strictly speaking, requires the erosion of a land surface. Nor does it seem unlikely that light bodies like *nummulites* might be removed, cast up by waves and enclosed in a rock so formed, without bearing any prominent or visible traces of having been rolled, in which case they would appear to have been enclosed where they had lived. An old shore line, if it could be pointed out in these deposits, would complete the analogy. This would of course indicate unconformity, but not among the shore beds themselves.

layers having few fossils. These are again overlaid by lumpy, marly, light-coloured bands full of *Nummulites*, *Bivalves*, a few *Gastropods*, some *Echinoids*, and a general assemblage of ill-preserved nummulitic fossils, the whole being succeeded by hard pale-gray or variegated compact *Alveolina* marble, often of a dull, yellowish colour, and generally forming the highest portion of the nummulitic limestone group. Perhaps the most constantly present beds of the formation are the hard *Alveolina* bands, but there are others of the more lumpy and earthy-looking light-coloured limestone, apparently lower in the series, also very generally present; they contain a characteristic *Gryphea*-shaped fossil. The *Nummulites* are of various common kinds, generally present in the Upper Punjab eocene; many of these are already described; but no thorough examination of the nummulitic fossils has as yet been made. The size of the *Nummulites* varies from extreme minuteness to nearly an inch in diameter. The *Alveolinæ* also vary in size from that of a grain of rice to three or four times the same proportions.

Characteristics.—The lumpy fossiliferous bands, the generally light colour of the rocks, their containing large sized *Bivalves* in some places and less commonly large *Gastropoda*, the occasional occurrence of some carbonaceous layers near the base, as well as the variable character of the whole group, are all points which tend to link the nummulitic group of this region with that of the Salt Range.

On the other hand, the presence of the greenish weathering clays or shales, the fine earthy or somewhat lithographic appearance of some of the beds, their pale colour, and their containing the large *Rotalinæ* so frequent in the Subáthu limestone and clay series, unite the formation, as exposed here, with that of the Subáthu series from the Indus to Murree, if not further eastwards.

Conditions.—The circumstances of deposition must with the advent of this series have undergone still further change, the muddy ferruginous waters so generally distributed becoming locally charged first with

mud of less ferruginous kind or sand, and occasionally pebbles, afterwards clear, either precipitating carbonate of lime, or crowded with lime producing animal organisms, or both causes for the calcareous accumulations may have existed. The presence of *Nummulites* has been usually taken to indicate deep seas; but from several features of the Subáthu nummulitic beds of the Upper Punjab, there may be reasons for doubting whether this were always a necessity of their existence.

Thickness.—The formation in this district varies greatly in thickness, the latter being of course very much increased if the gypsum and salt below be included. The uppermost calcareous portion is often a narrow band of hard limestone, showing extensively where inclined at a considerable angle, but where nearly vertical and crossed by ravines, the thickness is always found to be less than the display in the former situations would suggest. In many places the lower earthy part of the group is absent, unless represented in the *Sheenkoura* of the gypseous series, and for considerable distances the whole of the limestones have disappeared, leaving barely a few thin nodular, calcareous streaks to mark the separation between the red clay zone and the tertiary sandstones and clays overlying the nummulitic limestone group.

Where the red zone is present, as over most of the district, the lower limits of the limestone may generally be plainly seen, and the passage to the nummulitic clay shale and limestone can occasionally be closely examined, but the upper limits of the group are not always so clearly exposed. A rugged cliff line often occurs along the upper boundary owing to the sudden change in the texture of the rocks, and it is rarely, except in the clean cut sections of streams, that the junction between the limestones and sandstones can be inspected. Here the question of conformity or unconformity between the groups recurs to the observer as often as the contact is seen, the facts bearing upon which will be shortly alluded to in the description of the succeeding group.

Minerals.—The minerals of the nummulitic formation are few: some of the beds have a dolomitic appearance, and in some of the lowest

of the limestone portion of the strata nests of radiating spar were found, which gave the red Strontian flame before the blow-pipe, and probably consist of a mixture of this mineral with dolomite (or bitter spar). Some of the lower beds of the limestone also contain small nests of iron pyrites.

In some places just below the limestone part of the group are thin carbonaceous layers or pockets suggestive of the coaly bands very similarly situated in the Salt Range. They are, however, mere traces, and of no commercial value.

TERTIARY SANDSTONES, CLAYS, &c.

Three Sub-divisions.—Within this district the tertiary sandstone, clay and conglomerate series occupies by far the largest superficial area, and includes rocks which may be referred to each of the principal subdivisions of this great formation, as yet distinguished in the Upper Punjab, by the recognition of three groups or rather indefinite zones. These are as follow.

3. *Upper.*—Soft, bright-gray sandstones, and gray or orange clays with conglomerates largely made up of crystalline rocks often wasting into loose accumulations of smooth boulders. Bones may be occasionally met with.

2. *Middle.*—Gray and greenish sandstones and drab or reddish clays containing bones and fossil (exogenous?) timber in the sandstones. Reddish or red clays predominate below; and the beds pass downwards into—

1. *Lower.*—Slightly harder gray and purple or light-coloured sandstones frequently weathering, of a dark colour, and alternating with bright-red and purple clays. Calcareous and pseudo-conglomeratic bands occur frequently at intervals. The group contains *reptilian* bones below, with occasionally much (exogenous?) fossil timber, and close to the underlying nummulitic limestone, a thin reddish calcareous sandy layer has numbers of ill-preserved strongly ribbed *bivalve* shells.

Three zones also in the Simla Country.—Mr. Medlicott's researches in the Simla region of the outer Himáláyá have shown that there are also in that country on the flanks of the mountains and in the doons (dúns) below three main groups of these tertiary sandstones, conglomerates, and clays, but how far it may be possible to establish identity between the whole of these rocks as two sets of triple groups comprising lower, middle, and upper, or eocene, miocene, and pliocene, remains uncertain.

In that country each of the three divisions is separated from the next stage below by marked unconformity, while here no interruption to the most perfectly parallel superposition and sequence has been anywhere observed. The lower group, however, or Subáthu, would seem to be the same in both countries, its identity being based upon the recognition by Mr. Medlicott himself in the Murree hills and south of Káshmere of Subáthu characters* in the limestones, clays, and shales which are physically part of the 'Murree group' of the Cis-Indus, Upper Punjab. The upper part of this 'Murree group' he refers to the Dugshai type of the Subáthu rocks.*

These upper purple and gray 'Murree beds' (or Dugshai rocks) are identical in their general aspect and position with regard to the overlying series with those of the Trans-Indus group herein referred to the same place† (see list of rocks, p. 24).

The highest group also possesses characters which go far to link it with the Sivalik series of the Simla region, and, further, a series of fossils derived from beds near the Salt Range, having in places all the appearance of the upper division of this country, were determined by the late Dr. Hugh Falconer as Sivalik.‡

For the intermediate beds, if it were thought advisable to have but two divisions instead of three, they might without impropriety be included with the upper rather than the lower group. They resemble more or less the descriptions given of the Nahun rocks as recently demarcated by Mr. Theobald (M.S.S.)

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* Memoirs, Geological Survey, Vol. III, pp. 89 and 90. The valley containing "brown and variegated nummulitic clays." Trét and Sháh Durráh are in Ráwál Pindí, not Hazára district.

† See also Records, Geol. Surv., Ind., Vol. VI, 1873, p. 59 et seq.

‡ Paper on the Salt Range, by W. Theobald, Esq., Jour., As. Soc., Beng., No. 7, 1854. The late Dr. Falconer, however, made no distinction between the Sivalik and Nahun groups.

The whole series presents a great consecutive accumulation, the lower portion marked by greater hardness of the sandstones; their being, in certain zones, much veined with calcareous spar, and possessing a predominance of purple or red colours. Calcareous bands among the sandstones and clays, though seldom approaching to limestone in their nature, are not uncommon. As the series ascends, the red tint is limited to the clays and pseudo-conglomeratic concretionary beds, the sandstones having more of a bluish or greenish-gray colour, and still higher the clays become pink, drab, or orange, with occasional dark-gray layers. Here the sandstones become very soft, often of a shining whitish-gray colour within, or where crumbled down; and they contain strings of small pebbles. The latter increase in size and quantity till they become thick incoherent conglomerates or boulder beds sometimes cemented by carbonate of lime. The travelled boulders include a variety of igneous and schistose or crystalline rocks, believed to have been derived from the interior of the Himáláyán region. From their great hardness and smooth forms these pebbles and boulders have in many cases long outlived the beds in which they were laid down, and now thickly strew the ground, over large spaces, in which no boulder beds to furnish them could be found. The parent beds, however, may be seen *in situ* on both banks of the Indus near Makud and at the crags of Kaffír Kôt in the Wazírí country.*

The divisions between the groups are most indefinite, one passing into another gradually, yet approximate horizons may be so far identified in a general way that one can recognise to what part of the series any

* This place occurs in forbidden ground beyond the frontier. Not to lose a chance of acquiring information, a trusty messenger was requested to be sent by the Nawáb's people from Bahádur Khél, for specimens of the rocks forming the crag. Accordingly nine men, fully armed, left British India for the cliffs, and returned with some of the well worn blocks of purple quartzite, yellowish quartz rock, &c., so common in the upper conglomerates, which, they declared, they had extracted from the cliff-faces. Seen with a field-glass from one of the nearest points within the "red line," a distance of about twelve miles, the crags presented nearly horizontal lines of stratification, which may have been marked by the contained blocks or their cavities.—See below.

large exposure is most likely to belong; beyond this sub-divisions could only be indicated by arbitrary lines, drawn from palæontological distinctions which have not yet been ascertained sufficiently to be applied to this district.

Thickness.—The thickness of the whole series must be very large, but owing to its disturbed, folded, and, in places, dislocated state, can only be roughly estimated at 5,500 to 8,000 feet for the part visible, the uppermost beds having been denuded away.

Fossils.—Fossils, though not unknown, cannot be said to abound in this tertiary sandstone series; plant remains and obscure fucoid-like markings are common in the purple and gray lower rocks in which an exogenous (?) fossil tree as much as 60 feet in length has been found among the lowest 'Murree' beds. Higher up vegetable impressions, often carbonised, also occur, and fossil timber* is likewise to be seen in the middle softer sandstones, but the chief fossils of the whole series are bones. Remains of large *crocodile* jaws, polished, striated, pointed, teeth, ribs and other large bones, tortoise plates, &c., are to be met with, but broken, scattered, and difficult to extract from the sandstones resting almost directly upon, the nummulitic limestone. Associated with these, a thin layer of the shells of a large, strongly marked six-ribbed *bivalve*, ill-preserved in carbonate of lime, was found at a few places close to the above-mentioned limestone. Shells in any part of the series

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* From rough examination in the field, it is not easy even to say whether the fossil timber of the tertiary sandstone series is really exogenous or endogenous. This is not for want of specimens, but while these frequently present gnarled and knotted fragments, sometimes with appearances of branches having issued from within, the grain is generally straight, like bundles of parallel fibres, and as the cross section exhibits no structure, rings of growth or medullary rays are unseen. Some fragments of palm-like wood have been found, so that probably this timber may be of both kinds. No leaves, nor anything except thick fragments up to the diameter of considerable trunks, have been met with.

Specimens of these have been forwarded to Calcutta, but are as yet unexamined. The Salt Range specimens and those found here are identical.

are quite exceptional, and this is the only case of their occurrence known here.

Higher up in parts of the middle group, along with the timber abovementioned, numerous large fragmentary bones and occasional teeth or tusks occur in the soft greenish-gray sandstones of some localities; while towards the uppermost sub-division bone fragments are still to be met with, and have been found beneath the boulder sandstones of Makud, so that these osseous remains appear frequently, though sparsely, distributed through the whole series: reptilian remains apparently characterising its lower part here as well as at Subáthu according to Major Vicary.*

Conformity.—So far as the relative positions of the sandstones and clays to each other and to the nummulitic limestones are concerned, they are all conformable, but the fact of absolute and entire conformity of the whole series from the limestone upwards is not so clear. So much conformity as is indicated by perfectly parallel succession and by a short transition through highly calcareous sandstone (in some spots containing bone fragments) at the junction of these limestone and sandstone beds, (besides some other transitional features more limited in their range) may be found in any clear section. Where the limestone has all but died out, the part of it which disappears first is the lowest, and the upper limestone beds with those of the absolute junction continue till even these are gone and the contact layers alone remain to show that the succession continued the same everywhere, whether the limestone was present or not.

Again, the rocks of the sandstone series nearest to the limestone are always the same lower or 'Murree' rocks where displacement has not occurred. One peculiar band of small calcareous concretions disposed to weather separately, occurring over a large space close to the uppermost

* Quarterly Journal, Geological Society, London, Vol. IX, page 72, 1853.

layer of the limestone or to its place where absent from the section by reason of general thinning out of the whole group.

On the other hand, intimately associated with these evidences of conformity, there may be widely observed in the sandstone beds near the uppermost nummulitic limestone numbers of fragments, blotches, and pebbles of the upper *alveolina* and *nummulitic* compact limestone, or at least rocks exactly like these, and full of their fossils. The occurrence of these derived fragments in situations where the strong upper limestones have died away shows plainly that they must have come from some distance however small, and the only way that suggests itself to account for their presence without unconformity is that mentioned in the foot-note to page 57 regarding the similar occurrence of such derived pebbles down even in the basal portion of the nummulitic series.

Whether the explanation there given be accepted or not, the fact deserves notice, and, though considered insufficient to establish unconformity here, it is not against a state of things approaching thereto having existed, perhaps not very remote from the localities where the enclosed pebbles have been observed at various parts of the district.

These enclosed foreign fragments may be found over the whole district in the situations described, and it is known that they also occur in the same tertiary sandstone beds Cis-Indus in the Potwár plateau,* and along the base of these beds on the northern side of the Salt Range. Taking the whole broadly together, they may be said to range through a country 7,000 square miles in area, in which the junctions of the sandstone and limestone are repeatedly seen with the same conformity as noticed in this district, and if any total unconformity or discordance existed between the groups, it seems but fair to suppose that, along the many miles of boundary traceable through a region extending for 150 miles with the strike of the rocks, some evidence of excavations or

* Records, Geol. Sur., Ind., Vol. VI, p. 63. Somewhat similar rocks to those at the junction of the Trans-Indus limestone and tertiary sandstone are mentioned by Dr. Fleming at p. 353, and by Mr. Theobald at p. 670, of their papers on the Salt Range already quoted.

other erosive action upon the subjacent limestone rock, or some instance of complete discordance of stratification, would be found.

Conditions.—The great thickness of these tertiary sandstones, &c., and their endless alternation of arenaceous and argillaceous strata supposed to have been accumulated in shallow water, would point to a gradual subsidence of the basin, or lake, or sea which received them in order to allow of such a depth of beds being superimposed. A corresponding elevation of the Himálàyán rocks from the erosion of which they were probably formed may have taken place during a period which must have been protracted and longer still if the salt series and nummulitic limestone are all included, involving some uncertainty as to its early conditions when the waters, if not of the sea, must have at least been salt. Fresh water deposition may have succeeded, but there is nothing to define the exact place at which any change in this respect occurred, for the mammalian and fresh water reptilian remains could have been brought by rivers into the sea. And there is almost as little to mark the close of the epoch or link its geological events with those of recent geological time, the highest beds known having suffered denudation to an undeterminable extent, so that it is impossible to say what was the most recent conformable deposit of the period.

The boulder beds of the upper part of the formation, or what remain of them in this region, occupy situations which might favour the idea suggested in Mr. Medlicott's Memoir (so often referred to), that the boulders travelled through spaces approximately coinciding with existing lines of drainage, if their identity could be absolutely established with the rocks in the interior of this part of the Himálàyán region. The probability is strong that they were thence derived, and gathers still further strength from the upper beds being apparently the source of the Punjab stream gold, which is washed in a few localities in this region as elsewhere.*

* See Dr. Fleming's account in his Salt Range Reports.

Points indicating a general tertiary age for all the rocks.—If the rocks above described be considered collectively as a great consecutive series, there are some points connected with this to which attention may be drawn as favouring the idea that the whole belong to the tertiary period commencing with very early representatives of Eocene age.

The apparent intercalation of some purple sandstone and clay bands of the same aspect as those of the 'Murree group' with the nummulitic limestone, (though obscurity exists where disturbance and dislocation are so common,) would link the limestones to the beds above as much as the sequence to be found at the junctions which have been or will be described. Again, the red clay zone below the limestone, in its general color and aspect, bears so strong a resemblance to the red clays of the Murree group, that when accident brings the two into juxtaposition the clays are undistinguishable.

The occurrence of gray and white banded gypsum, such as may be found here, together with greenish-gray and red clays, often gypseous; nummulitic limestone, &c:, in the lower 'Murree beds' of the Ráwál Pindí district, admitted to be Subáthu, as well as the presence of gray limestone beds with a peculiar lavender tint, and containing in both localities only *univalves* or *gastropoda* of a discoid form, is an association of similarities which, added to the prevalence of petroleum or other earth-oil in both cases, forcibly indicates that the greater development of the gypseous, saline, and calcareous series in this district belongs to the same early tertiary, otherwise called Subáthu, age.

Leaving the difficulty of accounting for the absence of older rocks aside where tranquil succession is apparent, as has been already pointed out, we may infer from the presence of the red muds, purple sandstones, greenish gypseous shales, gypsum, limestone, bitumen or petroleum, together with the evidence afforded by fossils and by salt in one case and saline springs in the other, a prevalence or recurrence of certain conditions at a period elsewhere known to be nummulitic, all tending to confirm the idea formed on first seeing the rocks, and each point adding strength

to the identification of the whole as one broad system of results from causes or conditions appertaining to Eocene times.

Superficial deposits.—These hardly require any special notice. Coarse atmospheric, detrital accumulations predominate, and especially in the Tírí valley are scarped at different levels, as if that river in its wanderings had at certain periods excavated its channel with greater rapidity than at others, its power to do this being of course influenced by the height of the river Indus. Large surfaces of the Bánnú valley are occupied by gray sand derived from the tertiary sandstones; this also occurs in the lower part of the bed of the Tírí Tauí and in a tributary nullah from the south. A well-defined series of thick stratified deposits flanks the hills east and west of (Súrdág) village, and may probably form part of a vast detrital talus said to flank the Súliman hills near Bánnú. Calcareous tufa is exceptionally rare, while alluvium proper seldom exists owing to the rapid fall of the streams; nor have the analogues of 'Kadirs' been observed, but the sandy finer earthy and sometimes kunkery materials occasionally assume somewhat the appearance of loëss, not, however, here eaten into labyrinthine '*Kudderas,*' as in the Potwár plateau, Cis-Indus.

IV.—Extension or non-extension of the salt beyond this district.

One other point remains to be discussed before entering upon detailed descriptions of some of the sections to be found in the country, namely, how far the salt-beds of the series may be limited to the part of this region under British Government or within British influence.

From what has been previously stated, it will be seen that the rock-salt of the district *is one of the rocks of a series* which, whether considered as nummulitic or as part of the great tertiary system of the province, *is not necessarily bounded by any natural lines within the British Frontier.*

In the direction of the Manzullí or Threekanushpa range the clays and gypsum of the salt series hold westward along the frontier line beyond the last salt known, but the gypsum appears to be dying out, or its surface exposure lessening owing to the stratigraphical position of the adjacent beds.

To the northward of this place the nummulitic limestone looked upon as part of the same sequence continues also westward, forming hills nearly to the Kúram river, and to the southward, the axis of the Bahádur Khêl, disturbances diverging from those of Manzullí embrace a wide area of newer tertiary rocks crowned by the crags of Kaffír Kôt in the Wazírí country.

There are indications in the endings of the nummulitic anticlinals at Suppurrí and Luttummer that the axes of these are passing belŏw a great mass of newer rocks which, overlying the limestone, would effectually conceal the salt, but that this state of things does not continue is shown by the recurrence of the limestone, forming a conspicuous hill within the Wazírí territory north of Bánnú. The aspect of this hill from a distance is all that can be remarked upon, and it looks as if it was an isolated exposure caused by an upward arch in the axis, beyond which the tertiary sandstones, &c., from the appearance of the ground, might be expected to come in strongly in the valley of the Kúram.

It is confidently asserted by the natives of the frontier tract that neither *Speenki* (gypsum) nor *Malga* (salt) occur in this Wazírí country, nor anywhere westward of the frontier line, yet Dr. Verchere, in his geological paper to the Asiatic Society, already quoted, refers (at page 20, 1867,) to red marl and gypsum at the hot springs of Sir Oba* (probably Sar-Obáé, west of Bánnú), which may belong either to the salt series of this country or of the Salt Range; perhaps the latter.

The existence of marl and gypsum, however, would be no evidence that salt was also present, though of course the exposure of its associated rocks would, in the absence of better information, favour the possibility of its discovery.

The tertiary sandstones, clays, &c., have evidently a wide extension westward of this district, and if the lower part of the series was anywhere exposed, the accidental or natural fall of a cliff or stream bank might bring salt into view, there being no reason why it should not occur in other places as well as within this district, nor can precise limits be assigned to such salt deposits in any particular direction on general geological grounds.

It would be otherwise if the salt occurred in unconformable outlying patches, the remains of larger deposits, which might have been denuded from off the face of the country. Here, on the contrary, as has been shown, the rock-salt forms the base of a disturbed series, members of which stretch far away to the westward, and the likelihood of its non-appearance in that direction depends largely upon the physical structure of the ground, the prevalence of the massive upper arenaceous rocks, and the absence of faults or such upward curvature of the strata as would have brought the basal beds within reach of erosive agency in

* The place is unfortunately not marked on Dr. Verchere's map, but from information kindly supplied by Major Johnstone, Deputy Commissioner of Bánnú, appears to be situated beyond the frontier south of the Dour valley, and south of the village of Sokhél, between the Dour valley and the Khísor nullah.

There is another 'Sarobee' at the north end of the Chíchálí Pass, which is not supposed to be the locality meant.

hills, valleys, or ravines—the fact being always borne in mind that even if these erosive agencies exposed the gypseous series, as seen in this district, the salt need not necessarily be present, for it may have thinned out and entirely disappeared.

To the eastward the extension of the salt and gypsum series, if it continues in that direction, is buried beneath the sandstones and clays of the Potwár country, some indications of it perhaps existing (as suggested) in the gypsum of the Subáthu zone near the hills to the northward, or in the source of a brine spring at Kalra close to the southern foot of the Bakrálá ridge, not far from the Grand Trunk Road.

North of the villages of Láchí and Sireemeyla, both in this salt region, salt is unknown, but some of the streams issuing from the gypsum on the southern sides of the Gúrgúrlot hills are said to be saline, at no great distance from the salt-bearing tract.

Southward of the district, too, in the Sheen and Lawághar mountains, rock-salt is likewise unheard of westward of the Lún nullah, unless its existence be indicated by some saline springs many miles to the southward recorded by Dr. Fleming as "issuing from saliferous sandstones under carboniferous limestone near the village of Bahádur Dôk," not far from the junction of the Kúram with the Indus.* The Lún nullah salt is considered, for reasons already given, to belong to the Cis-Indus salt series, and any saline sources for these springs would from their description be referable to the same much older series rather than to that of this district.

If then the country to the north and south, where the rocks are known to be greatly disturbed, and lower beds than any found in this district are exposed, shows no extension of the local salt deposits, the presumption that they extend visibly to the west would be unreasonable, particularly when, as far as could be seen in this direction from the high-

* Dr. Fleming's Report, Jour., As. Soc., Beng., 1853, p. 260.

est hills,* the ground appeared to be mainly occupied by the soft upper tertiary sandstones, &c., in great undulating masses.

It is extremely unlikely in a country so traversed by herdsmen, if rock-salt were visible, that even small exposures of it would long escape their notice, or remain generally unknown, and, on the whole, it may be said that there is nothing in the geological aspect of the question to warrant the conclusion that salt exposures exist beyond the frontier, though its presence is quite possible whether exposed or not, and quite as impossible to foretell.

Had the existence of nearer salt been known during the great time these deposits have been worked, people would hardly have come all the way from Kábúl and other distant places with unladen animals to buy it here, and this seems a stronger argument against its occurrence in trans-frontier regions, than any geological reasons to the same effect, or to the contrary, bearing upon this most important point with regard to the British monopoly of the salt.

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* Far beyond the distance at which any rocks could be recognised, some high mountains in the country on the other side of the Kúram are probably formed of crystalline rocks, for granitoid *chuckkies (mill-stones)* were seen among the wandering Wazírís, who said they had brought them from that direction.

PART II.

DETAILED DESCRIPTIONS.

PART II.

DETAILED DESCRIPTIONS OF PARTS OF THE DISTRICT, WITH SKETCH SECTIONS ILLUSTRATIVE OF ITS STRUCTURE.

As the physical features of the ground arrange themselves naturally in four or five principal groups, and as these best exhibit the structure of the ground, it is intended to adhere to this natural arrangement in describing this structure or alluding to those places where noticeable points occur. These descriptions may therefore be conveniently arranged under the following divisions:—

1.—*The ground westward of Lachee or Láchi.*

2.—*The northern watershed of the Teeree Towey (Tírí Tauí) basin from the neighbourhood of Murdán Khél eastward by Malgheen (Málgín) to the Indus, and the hills about Weejoosum (Wijúsum) and Drubbokus.*

3.—*The nummulitic ellipsoid from Manzullí and Threekánushpa (Turkhai nushbo) to Bándá on the Kohát and Bánnú road; also the ridge thence to the Jatta ellipsoid near Zunuk: the nummulitic ellipsoid of Jatta and the imperfect one of Saya (Séya) Malgheen (Málgín) Salt Quarries.*

4.—*The hilly ranges and their neighbourhood from Bahádur Khél and Soordag (Súrdag) country to Nandrukki and Hokunni mountains.*

The plains and valleys between or adjacent to these features can be referred to where necessary as the remarks progress.

(For convenience of reference the spelling of the map will be generally adopted in the following pages, the official spelling being added in brackets).

1.—*The ground westward of Lachee.*

Lachee.

Lachee (Láchí), a considerable village on the road from Kohát to Bánnú, possessing an enclosed fort or structure which answers the double purpose of travellers' serai and rest-house as well as military post for frontier force. The place seems to be chiefly remarkable for the manufacture of saltpetre from the village refuse and soil, and therewith gunpowder of a coarse kind used for blasting at the salt quarries.

Hilly to the west of village.

The country may be briefly described as hilly to the west of the village, there being some four or five nearly east and west anticlinal axes of the strata coinciding with as many eocene limestone ridges. There are two considerable valleys opening towards, and other smaller ones occupied by, the tertiary sandstones, &c., these valleys being themselves hilly rather than flat, and having their heads towards the westward, so that the sandstone ground becomes deeply embayed among the nummulitic limestone hills.

Lachee: old salt quarries.

Close to Lachee (Láchí) one of these limestone ridges terminates, that particular anticlinal axis becoming depressed below the level of comparatively open ground to the east just before the ridge sinks; however, in perhaps the least likely situation for such an exposure, the limestone beds have been removed by erosion, displaying a good deal of apparently somewhat displaced gypsum in which deep hollows mark the sites of former salt quarries, the nearest or most accessible in the district to Kohát. None of the salt is now visible, nor is the place specially suited for mining, yet in other localities it would doubtless be considered a valuable possession.

Westward from the old salt-pits the ridge exhibits its anticlinal structure strongly, being covered with a thick sheeting of hard *Alveolina*

and *Nummulite* limestone sweeping boldly downwards and plunging beneath highly inclined beds of the tertiary sandstone series along the foot of the ridge on both flanks. Close to the limestone the beds are steady and nearly vertical, but further out in the valleys contortions are seen.

Junction scarp of limestone.

Along the sides of this Lachee (Láchí) ridge a feature not uncommon may be observed at the junction of the limestone and sandstone. It is this—the strong and steeply dipping limestone shows a low scarp on the dip side as if it had in places given way under the tension accompanying its contortion, and the débris from the face of the cliff thus produced, added to that which travelled down the slope, renders it almost impossible to observe absolute contact at such localities.

The following succession was observed close to Lachee (Láchí) old salt-pits:—Fig. 3.—

6. Nummulitic limestone.
5. Dun compact *Alveolina* limestone.
4. Darkish-gray limestone with *Alveolina*, &c.
3. Talus showing débris of soft light coloured gypseous clays, remains of a red clay band, &c.
2. Gypsum, whitish and gray, overlying, *unseen*.
1. Rock-salt.*

Ghorándí valley.

Proceeding up the long valley from Lachee (Láchí) westward by Tsunda, the stream of which becoming distributory apparently loses itself in the plains near Lachee (Láchí), the tertiary sandstones striking with little variation east and west are seen to be everywhere vertical, and as the valley contracts, high anticlinal or contorted limestone ridges enclose it on each side.

Anticlinal structure.

Of these ridges that to the north, or rather those, for there are two, exhibit the anticlinal curvature plainly like that at Lachee (Láchí), but the continuation of the latter south of the valley has a more complicated structure from the vicinity of

* With reference to the existence of the rock-salt at this locality, see Appendix.

Kole Sír, where portions of the tertiary sandstones rise on the hill obliquely, nearly connecting these beds with those of the valley south of Lachee (Láchí) ridge. This is apparently accompanied or caused by dislocation as well as extreme crushing and crumpling of the beds. A couple of miles to the westward near the village of Ghoráudí, a deep ravine from the nummulitic limestone hills south of the valley is occupied by the purple and gray sandstone and red clay of the tertiary sandstone series, apparently brought into this strange position by a small divergent synclinal curvature closely compressed and faulted.

Inlet of tertiary sandstones, &c.

Ascending the hill above Ghoráudí, immediately upon leaving the tertiary sandstone, &c., of the Murree group, and crossing a small talus of limestone débris, the nummulitic rocks whence it is derived may be observed cropping out strongly from the hillside instead of presenting an inclination more in conformity with its slope, as is the case eastward of the narrow faulted segment of the tertiary sandstones just now mentioned. On gaining somewhat higher ground above, the strong nummulitic limestone is seen to undulate boldly all over this part of the ridge, presenting numerous scarps to the northward, which were well marked standing out from snow that had lain some days when the place was visited. On the opposite side of the valley, in a rather north-westerly direction, the smooth anticlinal surfaces of the hills became broken, and bands of red clay appeared intercalated with the limestone.*

Hills south of Ghoráudí.

Continuing southward into the lower part of the Leeloohan (Lílúhán) Durrá or valley, a deep and narrow glen, these red clays were found high up on the southern sides of the hills cropping out among the contorted limestone beds, and were recognised as parts of the red clay

Leeloohan (Lílúhán) Valley.

* It is extremely doubtful if these red clays have any relation with the red zone. They resemble it closely, but present a strong appearance of interstratification with the limestones.

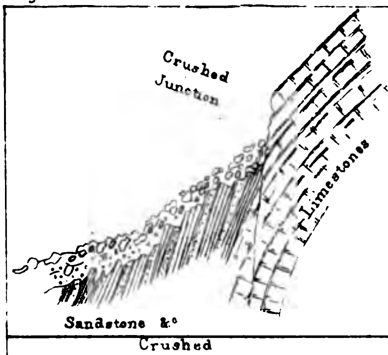


Fig. 3. Junction escarpment of Limestone

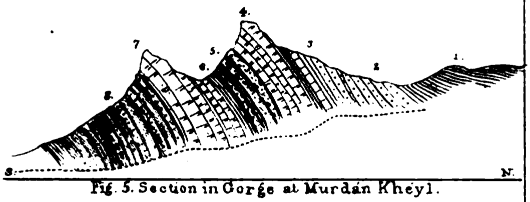


Fig. 5. Section in Gorge at Murdán Kheyl.

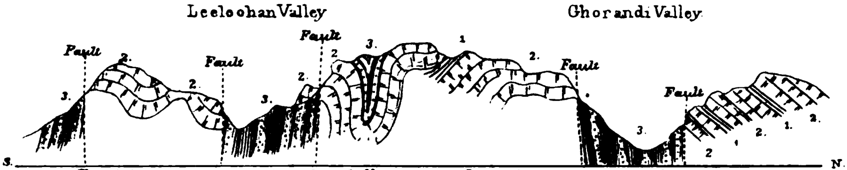


Fig. 4. Diagrammatic Section of the hills north and south near Ghorandi.

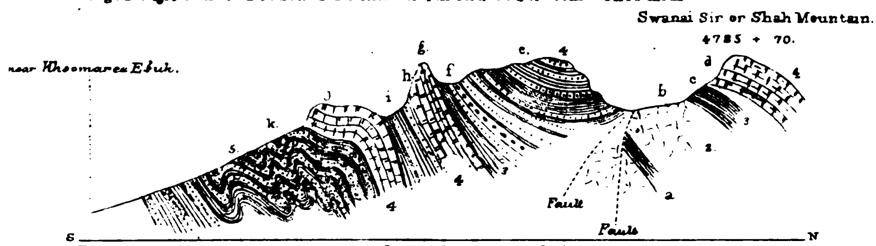


Fig. 6. Section up to Shah Mountain from plain to south in the Teeree Valley.

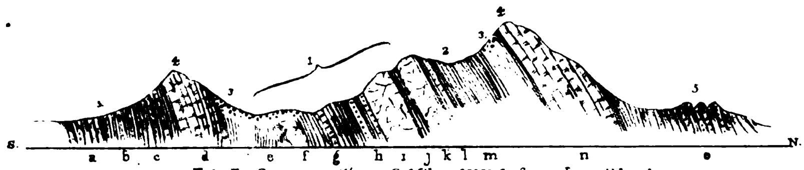


Fig. 7. Section 1½ to 2 Miles N.N.W. from Ismailkheyl.

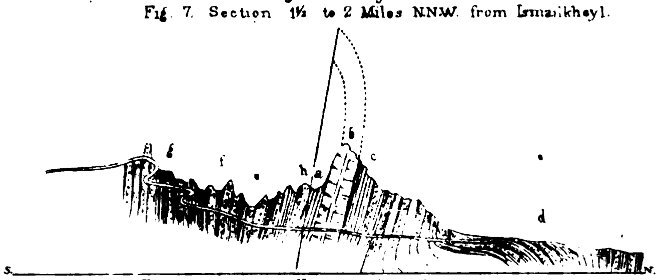


Fig. 8 Section at Karruppa incline.

Fig. 9 Section in little Pass south of Karruppa.

zone found everywhere beneath these nummulitic limestones, their exposure here being probably aided by obscure faults of no great amount. Before reaching the Leeloohan (Lílúhán) valley, as well as within it, the tertiary sandstones are met with again, separated by a rib of the nummulitic limestone. In this valley, for some miles above Momee (Momí) Khél, the sandstones and clays are vertical, striking up the glen, along the southern side of which the limestone rises abruptly with a scarped face as if separated by a fault from the sandstone beds.

Tertiary sandstones infolded and faulted.

Above this feature there is a small exposure of gypsum among the limestone hills south of Shukkar Khél between the Leeloohan (Lílúhán) glen and the larger Teeree (Tírí) valley. The general section across the hills mentioned is shown in Fig. 4. 1. Red clay in 2, Nummulitic limestone. 3. Tertiary sandstone and clay. F. Faults.

This small section* of some four or five miles in length will convey an idea of the frequently complex and highly contorted or dislocated state of the nummulitic and overlying rocks in this country. At the first glance one might suppose the vertical sandstones the oldest, and that the limestones had been removed from above them in the valleys by denudation, but this is shown not to have been the case, independently of other proof, by the folding of some of the same vertical rocks into the section at the north side of the Leeloohan (Lílúhán) glen.

Structure of section.

Westwards towards Deh Oomar (Dé Úmar) the hills rise and the nummulitic limestone spreads out, rolling over them with one larger synclinal than the rest, corresponding to the termination of the Ghoráudí valley. To the north and north-westward high nummulitic ground only could be seen, and it was asserted that in these directions the tertiary sandstones were rarely to be found among the hills or in the Bungush valley.

* This and following sections being diagrammatic do not always follow straight lines as it has been sought to express all general or prominent structures near them.

2.—*The northern watershed of the Teeree Towey (Tírí Tauí) basin and hills from Murdán Khél eastward by Weejoosum (Wíjú-sum) and Drubbokus nearly to the Indus.*

Nummulitic limestone on crests of hills, and soft lower nummulitics.

The nummulitic limestone as usual forms the high ground overlooking the (Tírí) valley near the Murdán Khél: yet here, though but ten miles apart, the sections differ much from that last given; a singular T-shaped glen, opening through a rocky gorge southwards into the larger valley near that village, having been eroded from a soft clayey and sandstone group in the nummulitic rocks unseen before and which predominates in this vicinity.

Inversion: Murdán Khél.

Besides the occurrence of different rocks, the usual amount of misrepresentation prevails in consequence of the inversion of the beds, a feature strongly developed here. Here, too, a band of rocks so identical with the lower tertiary sandstones as to be undistinguishable appears with all the aspect of intercalation between the nummulitic limestones, and follows their outcrop, dividing one band of these limestones from another.

In the gorge near Murdán Khél the arrangement shown in Fig. 5 may be observed—

Beds inverted.

8. Purple and gray sandstones and purple clays at mouth of the gorge dipping northward at 30°, and upwards, tertiary sandstones.
7. Thick *Alveolina* limestones dipping north at 55°.
6. Thinner and darker coloured limestone, nummulitic.
5. Bluish-gray coarse sandstone and purple clays identical in character with those of the lower tertiary sandstones.
4. Limestone thinner bedded than 6 and 7, darker and more shaly.
3. Lumpy, dark-coloured limestone with beds of platy shale.

In these a band of coarse light purple conglomeratic sandstone occurs, *apparently overlying* which only odd beds of limestone occur here and there in sandstones often conglomeratic with pebbles of limestone and crystalline rocks. The limestone bands contain both *Nummulites* and

Alveolina, the latter frequently, and the sandstone portion of the group may be from 300 to 400 feet in thickness.

Hard, greenish-brown, clayey, calcareous bands begin to appear, and at a distance of 15 feet below (but apparently above) fossiliferous nummulitic limestone, sandy beds contain pebbles of limestone enclosing *Alveolina* and *Nummulites*.

At this point in the section the glen within the gorge is reached and found to be occupied mainly by gray clays weathering of a greenish colour, often covered with a white saline efflorescence, and, though undulating at lower angles, presenting a conformable transition from themselves to the sandstone series at the head of the gorge.

Delusive appearance of section.

It is one of the most complete and delusive cases of the inversion so common in the district; all the aspect of the section from the lower tertiary sandstones to the south indicating *an ascent* to higher beds, among the highest of which derived pebbles of limestone resembling that in the section would be met with; and yet this cannot be an ascending section, for the same nummulitic limestone may be found both at Lachee (Láchí) to the east and near Durshái to the west, folding over anticlinal axes, and passing beneath the tertiary sandstones, &c., which are thus shown to be inverted here. One way of accounting for the fossiliferous limestone pebbles enclosed in contemporaneous rocks has been noticed already at page 57.

Shah mountain section.

Between three and four miles to the eastward of the section just described, the section from the Teeree (Tírí) valley up to the top of Sháh mountain also exhibits the inverted order of these beds with somewhat different features, the gypseous series being introduced by a fault or faults, and even more of these than are apparent being very possibly present.

Fig. 6 shows the section up to Sháh mountain from plain to south in the Teeree valley. The figures, &c., are explained below :—

2. Gypseous series. 3. Red clay zone. 4. Nummulitic series. 5. Tertiary sandstone, clays, &c. (Lower). F. Faults.

k.—Tertiary purple sandstones, gray sandstones and purple clays much contorted.

j.—Nummulitic limestone with hard, gray, and white marly lumpy layers; some slightly granular layers contain *echinoid* fragments and spines, *nummulites* rare.

i.—Bright red clay.

h.—Pale purple or brownish sandstone and red clay.

g.—White, marly, thin lumpy, and thin *alveolina* beds, and strong limestone. (This limestone band is apparently cut out by a fault to the east).

f.—Alternations of sandstones and red clay.

e.—Pale brown sandstone weathering dark brown and olive sometimes containing pebbles. Towards the upper part of the hill beds of clay of a greenish olive or gray colour predominate. Limestone pebbles occur in the sandstones, and there are small *nummulites* both in these and in the matrix.

c.—Red-clay zone. Fault or Faults here.

b.—White and gray gypsum dipping generally to the north.

a.—Greenish clay band in the gypsum.

The gypsum is overlaid by red clay (*c*) which possibly represents that at *f* and *i*, and this is succeeded by the strong nummulitic limestone (*d*) which forms the summit and northern surface of the hill, passing downwards into the Leeloohan (Lîlúhán) glen.

Shah-drung salt locality.

On the western side of Sháh mountain overlooking the eastern head of the T-shaped glen previously mentioned is the site of the Shah-drung salt in connexion with the gypsum, and just beneath the continuation of the red clay band (*c*) in the above section.

Dislocation as well as inversion obscuring the section.

The difficulty of understanding this section by reason of the inversion of the beds is increased by the dislocation of the rocks. Two zones of bright red clay not seen in the Murdán Khél section occur here at (*f*) and (*i*); one of these may be the representative of the red band (*c*) below the nummulitic limestone, but it is difficult to say which. In this section the reversal is even more pronounced, the nummulitic beds *j* absolutely resting with some horizontality for a short distance upon the lower tertiary sandstones, &c., and purple sandstones resembling these are found at (*h*) in the same place as the band (5) in the Murdán Khél section, and with the same appearance of intercalation, but less like ordinary tertiary sandstone. The positions of the rocks are so strange and there is such evident dislocation, it can only be suggested that the

Swani Sir part of the section once stood higher relatively to the rest; and after it subsided, the southern portion also sank, most probably along another line of fault. The ground is, however, very obscure, and where the best sections might be expected to be found, is overgrown by grass, *Kao*, and other bushes; a most exceptional occurrence in this country.

Gypsum in interior of an anticlinal.

Less than two miles eastward of this section the gypsum is seen to occupy the interior of an anticlinal fold or nose of the nummulitic limestone, bright red clay intervening between these two as shown upon the map. Some of the brown conglomeratic sandstones appear here also closely associated with the red clays, but so obscurely placed that it would be rash to say which was the newer rock, the probability being, however, that these brown sandstones are next older, in the local series, to the red clay over the gypsum, and thus older than the nummulitic limestones. The exterior portion of this anticlinal towards the Teeree valley shows nothing of anticlinal form, the nummulitic limestone dipping steeply the wrong way and presenting an escarpment to the south. Within the apex of the curve and on its northern side the beds assume their proper order, passing beneath a portion of the lower tertiary sandstone series, which is faulted into a small valley between the anticlinal and the western part of Shah or Swani mountain.

Lower nummulitic sandstone.

Mouth of Leeloohan (Lílúhán) valley.

For six miles to the eastward of this place, as far as the mouth of the Leeloohan (Lílúhán) glen, the nummulitic limestone presents a strong scarp to the south, rising above crushed and contorted folds in the tertiary sandstones along its base, these sandstones, where a general dip can be observed, appearing to incline towards rather than away from the limestone. The feature is suggestive of a fault, but where inversion prevails to such an extent as it does here, this is quite sufficient to account for the anomalous positions of the rocks, though faulting may also occur.

Detrital deposits in Teeree (Tírí) valley.

The portion of the Teeree (Tírí) valley overlooked by the hills lately described is open, but not level; most of the streams expose the tertiary sandstones, and the ground between often presents a considerable amount of shingle, gravel, clay, and such superficial accumulations arranged in the form of terraced hills, somewhat after the manner of the 'Karewah' of Kashmere, but not of equal extent.

Nearly horizontal beds in valley.

One broad group of hills occupying most of the valley from two to four miles east of the town of Teeree (Tírí) is instructive, showing how much less disturbed the rocks are in the centres of the synclinal valleys of the country. The sandstone and clay beds of these hills are in places nearly horizontal, or slightly inclined from the middle of the ridges on either side to a common axis near the middle of the valley, and as is common in such beds so placed they present strongly marked escarpments on the crop side.

Kole Sír: complicated ground. A salt locality.

The hills culminating in Kole Sír present a very complicated structure, sharp anticlinal and synclinal folds having suffered much disturbance and dislocation, in consequence of which there are numerous exposures of gypsum, the green clays associated with it, the red clay above it, and the nummulitic limestone overlying this, while the tertiary sandstones, &c., are found at different elevations around. Here also south-eastward of the summit where the largest exposure of the gypsum occurs is the rock-salt locality of Solthorbagar, described in the appendix.

Slippage of limestone.

Along the southern slopes of the hills the limestone appears to have slipped from its place sometimes *en masse*, and sometimes to owe its position to faulting. The sandstones of the valley, often of a hard texture and ash-gray colour, associated as usual with purple clays, appear close to the bases of the hills and for a short distance up their slopes. As usual also their dip

is reversed, leading the beds at high angles below the nummulitic limestone, but the junction of the two groups is generally concealed by débris of the latter rocks. Crossing this limestone the following section was found everywhere inverted :—

		Feet.
8.	Thick, compact *alveolina* limestone, white and yellow, very lumpy in places, and containing clusters of coral fossils impacted, and difficult to distinguish, about	30 to 50
7.	Thin, lumpy, and marly light coloured limestone full of fossils, *nummulites, oysters*, &c.	20
6.	Strong limestone full of very small nummulites	6
5.	Thin and thick regular limestone with few fossils, semi-oolitic looking ...	40
4.	Earthy-gray limestone with greenish shales, *nummulites*	15
3.	Remains of a band of cherty limestone of dark colour containing white fossil fragments, no *nummulites* found	21
2.	Red clay	15
1.	White, gray, and variegated gypsum occupying 60 yards of horizontal space, may be	100

Difference at each side of the section.

Crossing this gypsum mass at its northern side was found a thick zone of greenish clays not seen to the southward, and beyond it a thinner band of gypsum occurred, all dipping steeply to the north. Over the latter gypsum, the red clay previously met with was much more largely developed, and immediately succeeded by nummulitic limestone forming the crest of the ridge, the débris from which largely concealed the clay and gypsum just below.

Although there is a want of continuity, and the greenish clay would seem to be capriciously distributed through the gypsum, the steady high northern dip from the plain or valley to the south as far as the gypsum here must be considered inverted, this gypsum forming the centre of an overthrown anticlinal curve. The dip continues still high to the north, but after leaving the gypsum the order becomes natural; the nummulitic limestone of the crest is succeeded by the hard light-coloured *alveolina* marble, and the tertiary sandstones, clays, &c., which seem buried beneath the whole section, appear at top in the valley between this place and Lachee (Láchí).

Gypsum.

From the vicinity of the old salt-mines above mentioned, this gypsum stretches eastward between two bands of the limestone to a point due north of Ismaîl Khél, its general arrangement being that shown in the sketch section (Fig. 7), crossing the ridge, where the latter is comparatively low, north by west from the last named village. The numbers are as follow:—1. Gypseous series. 2. Red clay zone. 3. Talus débris and concealment. 4. Nummulitic limestone series. 5. Tertiary sandstone and clay series.

Section.

Inverted order.

a.—Purple sandstone.
b. c.—Purple and gray pseudo-conglomerate in red clays, (Murree beds), calcareous.
d.—*Alveolina* limestone.
e.—Green gypseous clay with hard gypseous layers, vertical.
f.—Strong, flaky, solid, white gypsum.
g.—Pale-greenish clay, with hard lime bands (*h*).

Natural order.

o.—Purple and gray sandstone and red clays (Murree beds).
n.—Hard dun and whitish *alveolina* limestone or marble.
m.—Red clay, very red above, purple and red with sandy ferruginous layers (*l*) below.
k.—Solid gypsum, reddish and flaggy above with black bituminous layers.
j.—Grayish-green clay.

i.—Strong white gypsum.

Disparity of the opposite sides of section.

This section is one of many which may be found in the country—showing but an inadequate representation of the former state of things. The double band of limestone with the gypsum between is a broad fact consonant with the structure of other places, but between these limestones the section, though rather well exposed, remains obscure, so that it is difficult to say where the axis of curvature may be. The red clay zone below the nummulitic limestone is strongly displayed to the north, (as in the preceding section), but what there may be of it to the south is concealed, and the nummulitic limestone itself is apparently thicker at the north than at the south exposure. If room for these beds to thin out to some extent over the curve (the distance across which is only about half a mile) be supposed, the difficulty would become less, but in its centre, where the bands on opposite sides would be much nearer each other, an even greater disparity is found, the gypsum and clay alternations not answering to each other. Crushing, compression and tension or traction

may have greatly modified appearances, yet still there would seem to have been much original irregularity in the arrangement of the different bands without the introduction of extreme dislocation by faulting which appearances would scarcely justify.

Interruption to easterly run of gypsum.

About two miles east of this section the east and west run of the ridge is interrupted by a sudden crush as it were from force exerted in these directions, the gypsum bulging out after becoming narrower even than where the section runs, and then being rapidly lost sight of eastward, where the ridge is formed by a thin rib of the limestone in continuation with the northern band shown in the section above.

Kurruppá incline.

There are some red clays seen at intervals among the débris on the south side of the narrow rib of limestone, but the second limestone band has disappeared, vertical purple and gray sandstones taking its place, associated as usual with red and purple clays.

The road from Kohát to Bánnú crosses this range, and ascends by a steep incline to a higher level at a place called Kurruppá, where there is a boorj or tower used by the men who convey the district post.

The nummulitic limestone here appears much crushed, its thickness reduced to a few beds of the hard *alveolina* limestone, and its dip has changed in the opposite direction, the rocks here underlying to the south at a high angle where not vertical; though not far from the northern end of the little pass, they assume open curves. Fig. 8 shows this section at Kurruppá incline. *a.*—Red clay. *b.*—Nummulitic limestone. *c. g.*—Tertiary sandstone, &c. *h.*—Probable fault.

d.—Soft, greenish sandstones and pseudo-conglomerate and purple clays.
c.—Red clay.
b.—Hard nummulitic limestone.
a.—Bright-red clay (possibly the band below the nummulitic limestone?)*

g.—Soft, greenish, and gray sandstones, and red and purple clays.
f.—Conglomeratic bed containing crystalline rock pebbles.
e.—Gray and greenish sandstones with predominating red clays.

h

* In such a case as this, it is often impossible to distinguish between the brighter red clays of the tertiary sandstones and the red zone below the nummulitic limestone.

Conglomeratic layer in lower tertiary sandstones.

One peculiarity observable here is the occurrence of a conglomeratic layer *f* containing scattered pebbles of quartzite and other crystalline or hard metamorphic rocks among beds which, both from their place and aspect, would seem to be some of the lowest of the tertiary sandstone series. Fragments of these older rocks have been mentioned as characterising the higher stages of the series, but their appearance below is quite exceptional, at least in the form of pebbles, or blocks.

Limestone rib to the east ending in an anticlinal.

The narrow rib of limestone continues eastward for about seven miles, forming the backbone of the ridge, which is flanked by vertical and disturbed sandstones and clays similar to those at Kurruppá. Towards the end of that distance it becomes slightly wider and terminates in an anticlinal 'nose' of considerable regularity, the axis of which sinks into the adjacent lower ground, the ridge disappearing at the same place, and the sandstone beds successively embracing the curved surface of the highest limestone layer.

The aspect of the ridge in the neighbourhood of Kurruppá would never of itself suggest that the limestone band belonged to part of such a simple curve as is seen here. To interpret such sections by appearances would manifestly lead to serious error, and the difference between these appearances and the fact will convey some idea of how enormously distorted is the stratigraphy of the district.

North of Ismaíl Khél another anticlinal.

Returning eastward by Kurruppá to the hills north of Ismaíl Khél, we find another horse-shoe anticlinal termination to the nummulitic limestone with which they are covered. Nothing in the general aspect of this hill at the place would suggest its structure, but at a little distance from the end, which, unlike the last, is presented westward, the sandstone and clay beds are found to come round in a bold curve, the southern side of which has a more gentle inclination in that direction than the northern

to the opposite, some of the beds there being vertical or even pushed over beyond the perpendicular so as to underlie to the south.

Gypsum and red zone within the curve.

To the eastward the anticlinal opens, its southern side disappears, being probably buried by a fault, and the northern part of the curve coincides with the ridge to the eastward, passing by Shúwukí. Just where the southern limb ends, a quantity of gypsum is seen within the curve at a place where 'salt mines' are marked upon the map. Here the ground looked as if it might once have been disturbed artificially, but none of the natives could give any information as to salt mines having been formerly worked at the spot: the presence of salt here is notwithstanding by no means an improbability.

A north and south section here through a little pass, used as a short-cut from the Jatta salt mines to Lachee, is given in Fig. 9.—

2. Gypsum. 3. Greenish clay with calcareous layers. 4. Variegated purple, red, and green clay with sandy bands. 5. Dark, cherty limestone. 6. Shaly, nummulitic limestone. 7. *Alveolina* limestone. 8. Very red clay. 9. Soft, greenish, and gray sandstones with a few harder bands and red clay beds. F. Fault.

Inversion.

This section, like that north north-west from Ismaîl Khél, is inverted, and liable to be misunderstood without due weight being given to the prevalence of inversion in many parts of the district.

Pass south of Kuruppá section.

Approaching the Little Pass from Kurruppá, ridges of soft, greenish sandstone highly inclined to the southward are met with in the little plain to the north. Clays among them are not much seen, being apparently concealed by surface deposits while the sandstones project. Similar beds are seen at the base of the ridge near the entrance of the pass, and higher up on the ridge close to the limestone deep red clays appear, much overshot by yellowish or buff débris from the latter. The limestone first met with is of the hard *Alveolina*-bearing kind, associated southward with more shaly layers containing *Nummulites*. All these beds dip to the south at 45°. Several yards further southward is a strong dark band of cherty limestone dipping

in the same direction and at the same angle. The chert of this band is white, and the limestone contains some obscure black fossil fragments, and granular knots or nodules. In the stream bank below the pathway as though overlying, at a little distance, the cherty limestone, are variegated purple, bright-red, green, gray, rusty, sandy and clay layers (14 in the section), and just beyond these variegated beds in the more open ground are hillocks of red and greenish clay with masses of contorted gypsum. Close to the southward of this some gray clays weathering greenish contain calcareous, lumpy, fossiliferous layers with *Cones, Oysters,* &c. Associated with these are red and gypseous clays with layers of deep liver-coloured sandstone, undulating over the ground with knolls of gypsum appearing from beneath the red beds, being overlaid by nummulitic limestone forming small hills, in the sides of which red débris is intermixed with the limestone detritus. The plain here between the pass and the Jatta hills is flat, but in the deeply cut river and stream valleys the soft, gray, greenish, and bright-purple beds of the tertiary sandstone series re-appear, with one very bright-red zone of clay, 150 feet thick. They strike east and west, and are either vertical or at high angles, generally dipping to the north, but show some greatly compressed synclinal curves.

Shúwukí limestone disturbed and reversed.

From this place eastward, to and beyond Shúwukí, the nummulitic limestone is greatly disturbed, often quite vertical or reversed above the tertiary sandstone on the northern flanks of the ridge, and with a talus of limestone débris upon the other, allowing little to be seen besides an occasional protrusion of gypsum.* The limestone is about 100 feet in thickness.

Focus of contortion and faulting near Sooddul (Súdul) and inverted limestone capping.

The part of this ridge between Kureerosum (Kurírosum) and Sooddul (Súdul) close to the termination of the smaller ridge from Kurruppá is a focus of intense contortion broken through by faults. The simplest

* The Jatta ellipsoid close to this part of the ridge described will be found mentioned below.

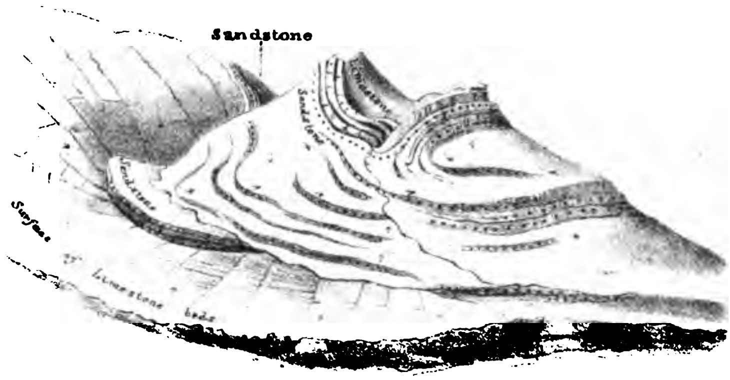


Fig. 10. South by west from Sooddul.

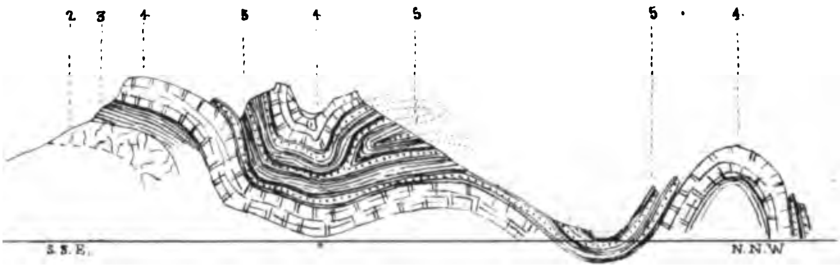


Fig. 11. South by west from Sooddul.

of these contortions is an oval, quaquaversal, dome-shaped sheet of the nummulitic limestone, just south of and about a mile distant from Sooddul (Súdul) village; but even this is faulted to the east, and sends a narrow band of the limestone southward to join that of the main ridge. The latter between this place and Shúwukí shows the nummulitic limestone on its northern side as a boldly curving convex sheet descending below the sandstones of the valley, but between this boldly curved sheet and the dome-shaped hill, a portion of the limestone is absolutely inverted so as to form a small cap upon a summit of the ridge which is mainly composed of contorted tertiary sandstones and clays. Fig. 10 is a diagrammatic sketch of the place from the dome-shaped hill, and Fig. 11, a section south by west from Sooddul (Súdul).—

2. Gypsum. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone, &c.

Extreme contortion.

The contortions necessary to produce this result are difficult even to imagine. If a second band of the nummulitic limestone were admissible, it would make things easier to comprehend, but no such second band was observed in the vicinity, and where there are so numerous evidences of extreme contortion, compression, and inversion in the district, it may not be too much to suppose this, one more among many strange cases of the strata being overthrown. The cap is a very small one; hence, perhaps, the difficulty of connecting it with curvature of the adjacent beds, but it must be remembered that the distorting forces which have operated in this district were sufficient to produce extreme results, and force the rocks into the most anomalous positions.

Another instance to the eastward.

Another instance of this is not far to seek, for within two miles to the eastward there are again obscure cases of superposition of the nummulitic limestone upon the lower tertiary sandstones at a prominent peak upon the crest of the ridge due north of Kureerosum (Kurírosum). The very aspect of this conspicuous knob, even from the village named, tells that it is of limestone,

but the tertiary sandstones may be plainly seen beneath intervening between it and the limestone which forms the crest of the hill.

On ascending to the spot, the escarpment of the southern side of the ridge is found (as usual along here) faced by a talus of débris, from which project some slipped and broken fragments of the limestone which forms the crest. Just beneath the 'edge' are traces of the red clay zone quickly succeeded by the nummulitic limestone of the scarp. This is at first nearly horizontal, but curving downwards becomes perfectly vertical here and along the northern side of the ridge towards the village of Malgheen, (Málgín). Following the curvature of the limestone are perfectly parallel bands of purple sandstone and clay with filmy, metallic *slickensides* as in many other exposures of the 'Murree group' or lowest of the tertiary sandstone series. At the contact of these 'Murree beds' with the nummulitic limestone is a band formed almost entirely of or containing very numerous small concretionary nodules of brown hæmatite elsewhere seen in a similar situation. These beds form the base of the peak, expanding also on either side as a thin patch to the west, but much thicker to the east. At more than half way up the side of the peak its capping of craggy *Alveolina*-limestone is reached, and the *apparently* lowest portion of this in contact with the sandstones is found to be a brecciated-looking bed very commonly forming the *uppermost* layer of the nummulitic limestone, and here containing the hæmatitic nodules again, as noticed at the normal contact between the limestones and sandstones beneath.

Alveolina limestone. Two other such outliers.

The capping is entirely of the hard *Alveolina* limestone, greatly weathered and not more than 25 feet thick, if so much. A smaller similar outlying cap occurs immediately to the north, and another longer one north of it, close to an anticlinal convolution of the ordinary limestone, ending suddenly close to the place, and used by the Mussulman natives as a conspicuous point whereon to light their signal fire, signifying that the new moon has been seen and the fast of the Roza accomplished.

Figure 12 is a sketch of the place in plan, and as viewed from the latter point. Fig. 13 gives section north of Kureerosum (Kurírosum).—2. Place of the gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone series. F. Faults. 4 A, 4 B, 4 C. Nummulitic limestone caps.

And Fig. 14 shows the caps of limestone north of Kureerosum (Kurírosum).—

A. Limestone. B. Sandstone and clay. C. Débris. D. Fault.

These three cappings of limestone lie within a distance of from 80 to 100 paces. The two southerly ones appear shaken and somewhat out of place rather than presenting complete conformity to the sandstones on which they rest; the contact of the other looks more natural, so that a second zone of nummulitic limestone was sought for, displaced fragments of which might have formed the other two caps. No such second parallel band of the limestone, however, could be observed anywhere in the vicinity, and where so much rock is exposed, if it were present, it could hardly escape notice. A fault which may have some possible connexion with the complexity here runs from west to east between the most northerly capping and the limestone anticlinal-turning north-eastwards apparently, for steeply dipping beds of the sandstone group run directly at the end of the curve within a short distance to the east, as shown in the sketch plan. Along this fault in a narrow ravine to the westward red clays are exposed as if cropping from underneath the nummulitic limestone, which close by to the north has lost its anticlinal curvature and forms a perfectly vertical rib. Another fault may perhaps run parallel to this between the two southern limestone caps accounting for the sudden change in the dip, from having a low northerly inclination beneath the two northerly outliers to vertical beneath that side of the highest cap.

Fault.

Red clays: limestone.

Probable fault.

The whole strike of this part of the ridge sets straight at a curved part of the escarpment to the west as though to run against the outcropping ends of its beds, and

Another a crossfault.

the dislocation at the junction would seem to require more than one fault to account for the positions of the rocks, the red clay zone, the gypsum, and thick greenish-gray clays of the gypseous series being all forced into strange positions by faulting or slippage, or both.

Regularity to eastward along outcrop.

From this place, for many miles to the east, considerable regularity prevails, and the ridge presents the same features,—a vertical rib of nummulitic limestone forming its centre and crest flanked on the north by equally highly disturbed or vertical sandstones and clays, among which a purple tinge predominates, and on the south by a steep talus covered with limestone débris, occasionally showing some protrusion of gypsum or some landslipped masses of the limestone from above, or from its colour indicating the presence of the red clay zone beneath the detritus.

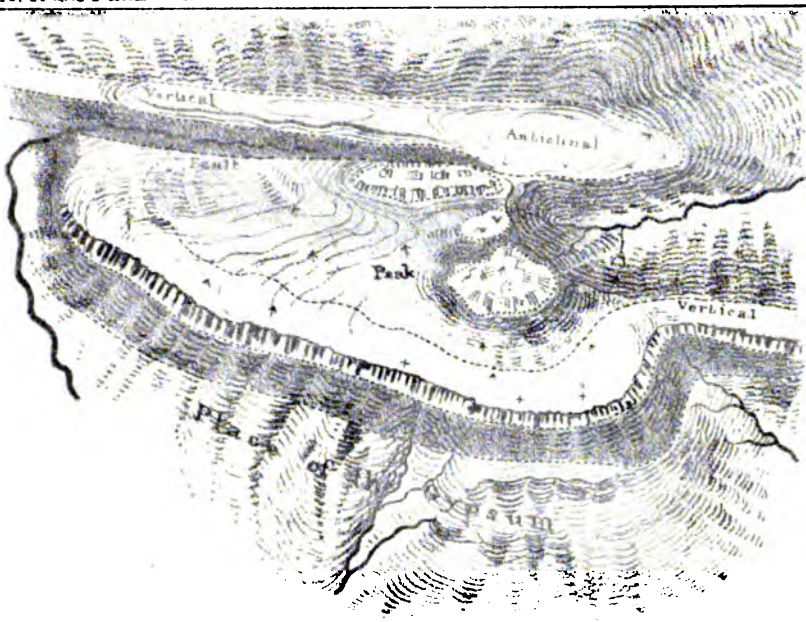
It maintains this character on the south side the whole way to the Indus, where it suddenly disappears, but on the north in the vicinity of Turwábeyrá (Turwábérá) it becomes connected with another parallel mountain about five miles in length, both rising together to a much greater elevation than the rest of the ridge.

Mountain between Turwábeyrá and Drubbokus.

All round this other mountain, one end of which overlooks Weejoosum (Wījúsum) and the other Drubbokus, the rocks and their arrangement are plainly visible. Along its whole length the nummulitic limestone occupies the highest ground, forming open, easy curves dipping from a nearly straight but broken scarp in southerly directions, where it becomes overlaid by the lower tertiary sandstones or Murree beds. These latter form two synclinal troughs, meeting endways on the high ground, and at one spot turning over somewhat as a horizontal cap covering the highest part of the ridge to the south.

Fine example of curvature of strata.

The regularity of the beautiful curves formed by these sandstone outcrops is but slightly disturbed at a place near the Indus termination of the southern ridge where the beds in the opening of the widest trough, eastward, form one



A. Limestone B. Sandstone and Clay C. Debris D. Faults

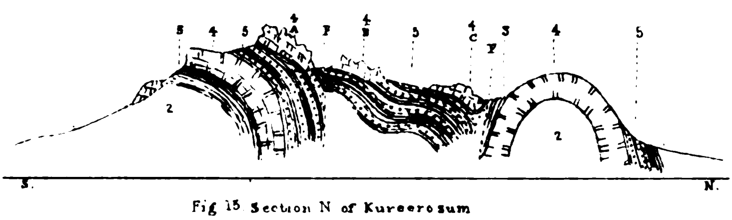


Fig 15 Section N of Kureerosum

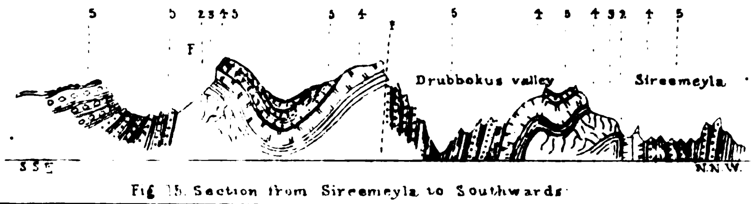


Fig 15. Section from Sireemeyla to Southwards

contortion within another. The axes of both these synclinals coincide with the fall of the valleys, each bed curving round within another, one side of each trough conforming to the continuation of the ridge from Ismaîl Khél, the opposite one to the southern slopes of the adjacent mountain.

At both the Turwábeyrá (Turwábérá) and Drubbokus ends of the latter long anticlinals may be traced, over the axes of which these sandstone and clay beds roll into the rocky valley between these places and the Sireemeyla (Sírímé1a) hills, but along and beneath the escarpment of the limestone between these villages the sandstones are all vertical or dip southward as though to pass below the limestone which they are elsewhere seen to cover.

Anticlinal termination of mountain.

Among these lower tertiary sandstones, fossil bones or bone fragments may be found, and in the deep valley between Weejoosum (Wíjúsum) and Drubbokus one greenish sandstone zone at least abounds with exogenous fossil-wood.

Fossil bones, and wood.

From inspection of the máp it will be seen that the ridges so far described have no absolutely fixed direction, but preserve their east and west course by gently deviating lines. Towards the localities last noticed there is a tendency to bend to the northward of east, an inclination which is further developed in the hills of the Sireemeyla (Sírímé1a) group.

Deviation from east and west course.

These hills, like those which have been lately described, are narrow ridges, formed of, or at least covered on one side by, the nummulitic limestone. The whole group rises more than might be expected, from the Kohát plains, but part of the apparent elevation may be caused by a sudden descent to the Indus, close to which they lie, and near which the ground is often rocky, rough and difficult.

Sireemeyla (Sírímé1a) hills.

The gypsum appears as usual either within an incomplete anticlinal fold or on the sides of the ridges opposite to those which are covered with the nummulitic

Place of the gypsum.

limestone, and the tertiary sandstones generally, have strongly the Murree aspect, purple sandstones alternating with bands of red clay. Over these the beds assume a greenish tinge, gray and greenish sandstones alternating with the usual reddish clays. One mass of these beds on the northern side of the ridge from Sireemeyla eastwards, steeply sloping and with serrated outline, repeats in miniature much of the aspect of the beds facing the high Sheenghur (Shínghur) mountains as seen from this district.

Tertiary sandstones forming serrated outlines.

Contortion of the whole group of hills.

The whole of these hills bear evidence of intense pressure, throwing the rocks into many sharp folds, the axes of which (as is often the case) maintain a certain horizontality for many miles, and then suddenly stooping below the level of the flatter ground disappear from view. The hills are also not more free from faults than elsewhere, the chief effect of which is to cause the total absence, sometimes for long distances, of the nummulitic limestone on one side or the other of the main ridges.

Faults.

Wirshund ridge.

The narrow isolated limestone ridge of Wirshund north of Malgheen (Málgín) has suffered such disturbance that the same limestone rocks which form a compressed anticlinal to the east are perfectly vertical along its crest and continue so to its western termination.

The general arrangement of the rocks will be understood from the section in Fig. 15, crossing the Sireemeyla (Sírimêla) ridge, the Drubbokus valley, and the mountains to the south.

2. Gypsum. 3. Red zone. 4. Nummulitic limestone. 5. Tertiary sandstone, &c. 6. Upper ditto.

Sireemeyla rock-salt locality.

Within a mile to the south-eastward of Sireemeyla (Sírimêla) occurs the last known exposure of rock-salt in this direction, (it will be found described in the appendix). The salt occurs as usual closely associated with gypsum, a long and narrow stripe of which runs from beyond this place towards Weejoosum (Wíjúsum), forming the core of the limestone hills,

and bordered by the red clay zone, which constantly underlies this limestone. Just at the place where the salt occurs there is a deep narrow valley leading the drainage to the Indus, and finding its way (as is frequently the case) right across the most southerly of the Sireemeyla (Sírímćla) rídges. This valley is occupied by vertical or highly inclined purple Murree beds, from which one walks directly on to the gypsum, the junction being effected by a fault in which at a little distance to the eastward a fragment of the limestone remains wedged as if to show that but for this dislocation it would have been continuous.

Fault.

At the Weejoosum (Wíjúsum) end of this ridge the anticlinal structure is somewhat seen, but more strongly pronounced in the sandstone rocks, which, curving round, embrace its termination between that village and Chushum Bándá. Along the south side of the ridge the nummulitic limestone with many contortions shows itself always on high ground as far as the gorge by which the stream from Sireemeyla (Sírímćla) escapes southward; but here changes sides, lying upon the northern slopes hence to its eastern end.

Anticlinal north of Weejoosum (Wíjúsum).

Close by the village last named another ridge commences, having the limestone also on its northern side, and the usual talus or débris covered slope to the south.

Sireemeyla (Sírímćla) ridge.

Near the eastern end of this are the sulphur pits of Gunjully, in alum shales just at, or slightly beyond, the border of the map, but deserving of mention here, the place having the reputation of being formerly worked to a considerable extent.*

Alum shales and sulphur pits, Gunjully.

* The place is wrongly shown upon the map at the northern base instead of the southern side of the crest of the ridge, the error being one of from a mile to two miles. Prismatic compass bearings to fix it made Sookawur (Súkawur) Húkaní summit south 30° west, the summit of the mountain between Drubbokus and Turwábeyrá (Turwábéré) south 38½° west, and the junction of the Teeree (Tírí) Taní with the Indus south 8° east. The locality is referred to by Dr. Fleming (see Report As. Soc. Jl., Beng., 1853, p. 348) as having produced 1,000 Lahorí maunds of sulphur annually, but it is not now worked, though the sulphur might be made available for the blasting powder factory at Láchí, only twenty-four miles distant.

These black alum shales or sulphurous beds are situated close to the top of the gypsum apparently, but within it and not far below the nummulitic escarpment forming the crest of the ridge overlooking Gunjully. The whole of the associated beds are here intensely disturbed and thrown into sharp contortions, while immediately to the south a reversed fault makes the tertiary sandstone and clays at their junction with the massive white gypsum appear to dip beneath the latter.

The shales are in places very carbonaceous-looking, and on their weathered surfaces plates of selenite are lying, which have been apparently weathered out from them. Chemical reactions seem to be actively going on, the whole place emits sulphurous fumes, the pyrites in the shales is mostly decomposed, and the alum on surfaces of the rock acts strongly on one's hands. Native sulphur occurs on the sides of small cracks in the shale, small portions of which were easily ignited by a lens.

3. *The Nummulitic ellipsoid from Manzullí to Bándá on the Kohát and Bánnú road, &c.*

Rocks as seen from Rágo-tungí Sír northerly view.

On ascending the Manzullí or Threekanushpa (Thríkanushpa) ridge near Rágo-tungí Sír, the Dullun valley, or plain, at the head of one of the branches of the Teeree Towey (Tírí Tauí) river is seen stretching away on the north side of the ridge to the Koorum (Kúram) river. In this valley there is not much rock seen, but what there is within view forms a continuation of the tertiary sandstones and clays of the Teeree (Tírí) valley. Rising from the latter between the two southerly head-waters of the Teeree Towey (Tírí Tauí) is the long anticlinal ridge of nummulitic limestone, round the nearest or Dumbáro end of which the sandstones are seen to bend northward from the village of Amán Kôt. This ridge, as far as it can be seen, appears formed of the same limestone, with the sandstones on its flank, forming the northern side of the Dullun plain.

Southerly view.

Southward from the Threekanushpa (Thríkanushpa) (on the map Turkainushbo) ridge extends part of the country of the Wazíris, formed of a central somewhat elevated mass of soft undulating sandstones, supporting the crags of Káffir Kôt, a rocky depression intervening between this mass of sandstones and the point of view occupied by the lower beds of the tertiary sandstone series.

Triple structure of Manzullí range.

Between the Wuzírí (Wazírí) country and the Dullun valley the Manzullí range has a triple structure, each of the three parallel ridges having a limestone crest. Of these the most northerly is the inverted north side of the Manzullí and Bándá ellipse; the middle one corresponds to the southern side of the same, and the other is a narrow separate anticlinal divided from the rest by the overlying sandstones and clays. This anticlinal seems to have been broken through or eroded so as to expose some of the underlying gypseous clays. The place is, however, inaccessible, being within the

Wuzeeri country. The middle ridge of this western part of the range is also the highest, and here forms the boundary of British India. Its southern side is covered by contorted tertiary sandstones, clays, &c., of the Murree group, but in the valley to the north, the green clays (*Sheenkoura*) of the gypseous series, and the overlying red clay zone, occupy the space between the opposite limestone sides of what was once an anticlinal curve, the gypsum itself not being seen.

Highest ridge, British Boundary.

Just at the top of the ridge, and nearly due south of the village of Goorgoori (Gúrgúrí), the contortion is extreme, the nummulitic limestone being bent into such a curve as that shown in Fig. 16, (3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstones.) And apparently faulted against the flanking portion of the tertiary sandstone series. Caps of the latter rocks occur in more places than one, resting upon the limestone, and at the base of that shown in the sketch, the junction of the sandstone and limestone is effected by a passage bed in which lumpy nodules of the limestone, the size of one's fist and under, are enclosed in a sandstone base. These nodules become more numerous downwards, and within a few inches or a foot, the sandy matrix disappears, the upper layer of the limestone being a lumpy bed formed of the same nodules as occur immediately above. Besides this evidence of transition, there is in the nummulitic limestone here a single bed of greenish sandstone precisely resembling that of the tertiary sandstone series; it is 15 feet thick where measured, and intercalated between the limestone beds.

South of Goorgoori (Gúrgúrí).

Transition from the nummulitic limestone to the tertiary sandstone.

The valley between this place and the southern of the three ridges is occupied by closely contorted sandstones and clays, some of the gray sandstones near the mouth of this valley containing conglomeratic layers, (noticed at the ascent on the road south of Lachee (Láchí) as an unusual occurrence). Further south into the lower ground about Bahádur Khél contortions are still found for

Adjacent valley in Wuzeeri(Wazírí) country.

three miles from the hills, the gray sandstones becoming soft and alternating with darkish-gray and brown clay as the Kaffír Kôt mass of sandstones is reached.

Anticlinal eastward of Rágo-tungí.

Eastward of the Rágo-tungí and Turkainushbo Sírs* the sides of the anticlinal separate; it is flanked by two smaller anticlinal folds, one on each side, both of which expose the nummulitic limestone: indeed, that to the south also shows in a deep ravine some of the immediately subjacent beds.

Green sandstones in the lower tertiary sandstone series.

In this country greenish sandstones in thick or thin groups are not uncommon among the lowest or more decidedly purple tinged portion of the tertiary sandstone series. A strong zone of these flanks the southern side of the range north of Bahádur Khél, giving its side a distinctly green tint. This results very much from the position of the rocks, large portions of their surfaces being presented to the plain or valley, while the intervening clays stripped from these by erosion are hidden in small depressions, their concealment being no doubt largely assisted by the numerous arches into which the beds have been thrown.

Limestone (south side of hills), and other rock.

The limestone zone of the southern side of the hills is everywhere intensely disturbed, often vertical, and sometimes bending over to the north, as though to rejoin that of the opposite side of the ellipsoid; just below it the usual red clays are sometimes visible, but more frequently concealed by nummulitic débris. Here, too, closely associated with the red clays of the red zone are disturbed masses of the brownish sandstones and gray clays or shales seen north of Murdán Khél and on Swánaí Sír Mountains, while in the centre of the range even forming some of its highest ground at the Manzullí *boorj* or *chowkí* the gypsum appears strongly in great masses alternating with gray or greenish gypseous *Sheenkoura* clays. The rock-salt

* Called by the natives Raothungi and Threekanushpa.

Salt localities.

is obscurely seen in a few spots mentioned in the appendix as the Manzullí localities. The sketch section given in Fig. 17 crossing the range south-west of Amán Kôt will convey a bettèr idea of the state of things than any elaborate description. The range is here about two miles broad.

1. Rock-salt (place of). 2. Gypsum and clay. 3. Gray clays, brown sandstones and thin limestone layers, nummulitic. 4. Red clay zone. 4. Place of ditto. 5. Nummulitic, lumpy, and *alveolina* limestone. 6. Lower tertiary sandstones and clays, the very lowest of the former, in places conglomeratic. F F. Faults.

Oblique result of the contorting force.

The general obliquity of this section would suggest that the contorting north and south pressure was transmitted through the rocks at a considerable depth from the then surface of the ground towards which the opposing resistance proved strong enough to cause an underthrow of the whole section towards the south.

The region of this disturbance may have been considerably more deeply seated than the present place of the contortions when it is remembered that hundreds or even thousands of feet of upper tertiary sandstones and clays may have once reposed above the highest beds of the range.

Disparity of opposite sides of contortion.

The disturbance, though great, seems not to have been limited to the ordinary anticlinal and synclinal curves, but dislocation also, as one result of tension, apparently took place. In the centre of the main fold of the ridge where the rocks might be supposed to have had least room for alteration or motion, a certain disparity of the bed of the gypseous series and those close above the latter on each side of the axis may be observed (similar in a general way to that noticed regarding the sections north of Ismaíl Khél), so that both sides of the anticlinal within the hard nummulitic limestone are not close counterparts of each other. It may be supposed that the curve of the beds now incomplete was sufficiently extended to have admitted of some lateral changes during deposition, sandstones and clays predominating at

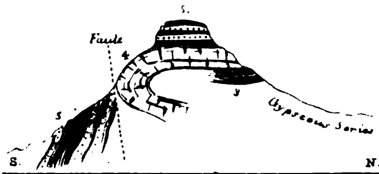


Fig 16 Curve in Nummulitic Limestone near Ragetangi Sir.

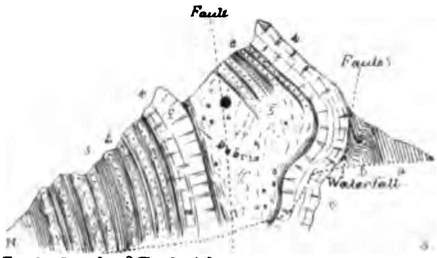


Fig 20. Sketch of Fault (*Producing appearance of a synclinal*) Water fall South of Mevlukilla.

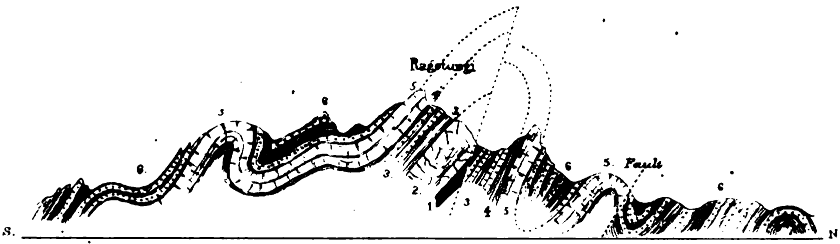


Fig. 17 Section across hills S.W. of Amankot. Range here about 2 Miles long

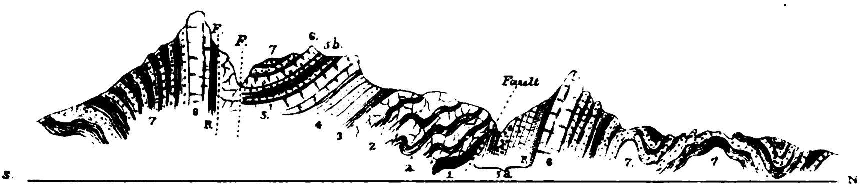


Fig. 18 Section across hills S.W. of Sharki.

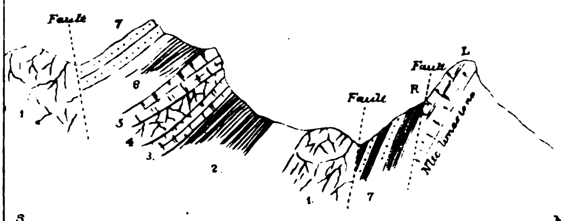


Fig 19 Outlier of Nummulitic beds near Surtung.

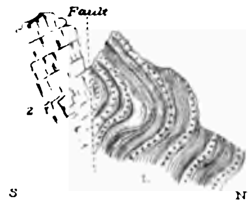


Fig. 22 Junction of limestone and Tertiary Sandstone Merand. Pathway.

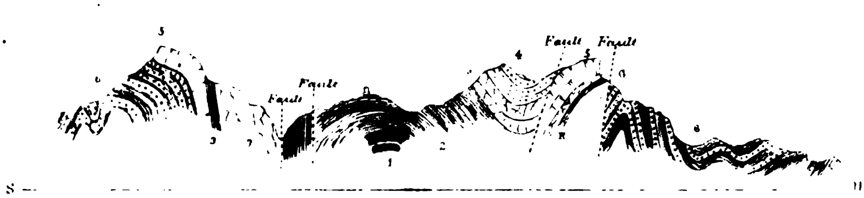


Fig. 21 Section at (Surtung) Salt locality W. by S. from Tiri

one side over the gypsum and limestones and clays at the other. In a sharp curve like this, the sides of which are pressed into parallelism, whole groups of layers might have been squeezed out of their places in the curve. Something may be attributed to the existence of the salt, strong traces of which are present, and the removal of which by solution could well be supposed to have initiated lines of weakness, inducing displacement quite irrespective of any kind or amount of contortion which might have occurred.

Local differences.

In approaching the region of this section from the north or south, any ravine from the hills might show a local difference; along the line taken the lower tertiary sandstones and clays appeared at the north side as above, while other contortions off the line could also be seen, one of them coinciding with the conspicuous northern limestone arch.

Limestone pebbles in lower sandstone of tertiary sandstone group.

Among the gray sandstones and red clays, close to these northern exposures of the limestone, are a few beds of calcareous pseudo-conglomerate, containing fragments, nodules, or pebbles of a rock exactly like the adjacent limestone, but showing no signs of unconformity.

Inversion.

The limestone is whitish and lumpy, of the *Alveolina* kind, and seems to include a small lenticular mass of red clays. This limestone zone where the usual 'bad step' caused by it occurs a little further south, does not seem to be more than from 50 to 70 feet thick, and owing to the inversion has the appearance of being overlaid by gray clays and sandstones with some purplish bands, amongst which are limestone layers containing nummulitic fossils.

Southward of these are gray clays close to the few and small exposures of the rock-salt seen hereabouts. These are presumably faulted against masses of white amorphous gypsum.

Brown sandstones and gray clays: lower nummulitics.

Overlying this gypsum in proper order, gray clays occur again, the red zone usually occupying this position being apparently dispersed among the gray series, with some representative bands above near the base of the overlying limestone. Over the gray clays are several feet of light brownish sandstones rarely conglomeratic, and quite similar to that of Sháh mountains (Swánaí Sír). The immediately succeeding *Alveolina* limestone does not always form the very crest of the ridge. It projects at Rágo-tungí peak, but close by to the east sinks into the face of the northern cliff, leaving the succeeding sandstones (here containing a few small pebbles) to form the ridge.

Contortion.

From the crest southwards the ridge exhibits much folding and contortion of the limestone and sandstone beds, the red clay zone being seen in its proper place apparently, just within a large anticlinal curve of the limestone.

Inversion.

A mile or so to the eastward of this section where the path to the Manzullí Chowkí runs, the southern side of the anticlinal is inverted, the nummulitic limestone being again overlaid by the gray argillaceous beds, and purple sandstones and red clays intervening between these and the gypsum, but at a short distance further east, at the Thôrdrung salt locality, the series regains its natural order, bending from the south over the ridge into a long central glen of the range.

Rock-salt.

A little rock-salt is here seen under a cliff of gypsum much over 100 feet in height, above which comes débris of greenish clay for nearly 200 feet more, then red clays obscurely seen, and then the nummulitic limestone on the crest of the ridge covered by a thin cap of the tertiary sandstones.

Section south-west of Sharkí.

The next section to be noticed crosses the ellipsoid near the meridian 71° east, the rocks being very much the same, but the contortion seems here even surpassed

by dislocation. Fig. 18 shows this section across the hills south-west of Sharkí near longitude 71° east, about three miles in length.

1. Rock-salt. 2. Gypsum and greenish or gray clays. 3. Gray clays. 4. Light brown sandstone and débris. R. Red clays. 5. Nummulitic limestones (lower ?). 5a. Nummulitic sandstones, limestones, and gray clays, limestone layers containing *Alveolina, &c.* Some purple clays and sandstones. 5b. Purple sandstone and red clay (very like No. 7). 6. Hard nummulitic limestone. 7. Tertiary sandstone series. F. Faults.

The principal points in this section are the absence of the two lateral anticlinals seen in the east, the limestone not reaching the surface, the development in the lower part of the nummulitic group of limestone and sandstone bands, the former fossiliferous and the brownish sandstones of this horizon, being limited as before to the south side of the principal anticlinal axis, near which and near the little rock-salt seen the section again appears to be faulted. The absence of the red clay zone elsewhere so persistent in its place at the top of the gypsum (unless cancelled) appears strange, while it is found on the inner side of the nummulitic limestone to the south. Another peculiarity is the apparent intercalation in the nummulitic limestone of a zone quite resembling the overlying lower tertiary sandstones, and the occurrence of a mass of the two latter groups faulted into the gypsum area and apparently structurally different as to details from the nummulitic border on either side of the ellipsoid.

Tertiary sandstones, &c.

Approaching this section likewise from the north, the tertiary sandstones and clays are found much disturbed and vertical in the Tírí valley: towards the hills they assume open curves, and at foot of these a red clay zone is conspicuous among them. In a ravine up which the road led they become nearly vertical, again consisting largely of gray sandstones inclined at high angles to the west of south. The nummulitic limestone has the same somewhat inverted dip, changing to vertical, and a thickness of about 160 feet where the usual hard band crosses the gorge, forming one of the difficult little

Nummulitic limestone.

passes common along the limestone zone. Above this apparently, but really of older age, come the following, arranged in their natural order from the limestone of the gorge downwards, as seen in the stream bank:—

Detailed list of beds at 5a in Section above lower nummulitic series, bedding vertical to south-west at 70°-80°.

No.	Bed	Feet.
15.	Greenish clay and earthy limestone in thin bands overlying a layer of oyster fragments	5
	Interval of 50 yards, probably soft beds.	
14.	Purple sandstones	2
13.	Gray clay	
12.	Sandstone layer	
11.	Gray clays	
10.	Purple clay	
9.	Purplish and gray clay alternating with layers of sparkling sandstone	80
8.	Earthy, calcareous, sandy *Alveolina bed*	
7.	Sandstone and gray clay alternating	
6.	Gray clay	12
5.	Greenish-gray, lumpy, impure nummulitic limestone	20
4.	Greenish, gypseous clay faulted.	
3.	Mass of crushed green clay and shales, with hard, flaggy, lumpy bands, the latter full of Nummulites. All much contorted, any clear dips to south-west, exposure 150 yards.	
1.	Oblique fault and place of rock-salt.	
2.	Gray, smooth, and gypseous clays alternating with masses and laminated bands of gray and white gypsum.	

Displacement.

These latter beds, (the gypseous series), are pushed over, or obliquely faulted, so as to overlie the beds No. 3, and at the junction the small salt exposure of Zawa-drung occurs.

Greenish clays next to salt.

The rock-salt here is immediately covered by greenish clays, over which a portion of the gypsum is seen.

Disturbance in gypsum.

The whole of the gypsum exposure here is much disturbed, undulating gray clays being among the lowest beds seen. These clays present strong interstratifications with the gypsum, but much of the latter gives no sign of its arrangement, though, on the whole, there appears to be a tendency among the undulations of the mass to dip in a southerly direction.

The Tírí and Bahádur Khél valleys north and south of section.

The Tírí and Bahádur Khél valleys in this vicinity, respectively north and south of the range, are open, the former particularly presenting numerous detrital terrace-like scarped hills. Notwithstanding these detrital accumulations, and probably resultant from the action which scarped them, there are numerous exposures of the rocks below, either in stream valleys or projecting reef-like through the surface, the angles of inclination of their strata being frequently smaller at some distance from than close up to the hill ranges or on their flanks. In the Tírí valley the beds have, on the whole, rather an older aspect than to the south in the Bahádur Khél country, towards the centre of which valley pebbly beds and their débris are sometimes met with. As a whole, the beds of both valleys may be described as a great accumulation of gray sandstones and red clays, the sandstones becoming harder and often of a purple tinge, below, near the nummulitic limestones. In the latter situation they often contain somewhat indefinite small and fragmentary plant remains, while occasional pieces of fossil bones may be met with almost anywhere.

Plants and fossil bones.

Interior of ellipsoid near Soorthung (Súrtung) Sír.

Soorthung or Soortung Sír (Súrtung) is the name of one of the most lofty peaks in the country (4,329 + 70 = 4,399 feet), and certainly the highest on this range. In the broken lower ground forming the interior of the ellipsoid near it, one of the summits is formed by another detached group of the nummulitic rocks faulted into its present position, and occurring as an isolated patch upon the gypsum series. In this

Bands of gypsum in the lower nummulitics.

patch and to the eastward the sections again differ from those above described; one or more thick bands of gypsum occurring in the basal part of the nummulitic series; and a 20-foot bed of this gypsum being seen to thin away to nothing within a short space in the scarped out crop along the northern side of the patch itself.

Fig. 19 shows the outlier of nummulitic beds near Soortung (Súrtung). 7. Brownish sandstones. 6. Soft beds. 5. White limestones. 4. Gypsum thinning out. 3. Whitish limestone. 2. Greenish clay in talus. 1. Gypsum.

Gypsum.

Just to the north of the gypsum (No. 1 above) brown sandstones and shales appear on the inner slopes of the northern limestone rib at 7[1] so that there would seem to have been considerable disturbance and faulting at this place.

Red clay zone.

The red clay zone so intimately and constantly associated with the upper boundary of the main gypsum mass does not appear in its place, but there is a band of red clays at R. between the brown sandy beds and clays at 7[1] and the nummulitic limestone L.

Inconstancy of sections here.

The whole of the sections in the neighbourhood seem to be less constant or more irregular than usual, as if the different groups admitted of other bands of the same character as the neighbouring ones, and probably formed under recurrence of the same conditions, being included amoug them. Thus gypsum layers are seen interposed between limestones and red clay, and sandstones of a purplish colour occur also among the lower layers of the nummulitic series.

Faulting.

The faulting and disturbance of this part of the range are as prominent as usual. The high summit of Soortung (Súrtung) is formed of the tertiary sandstones

sloping slightly to the northwards, and faulted against vertical nummulitic limestones, between which and adjacent gypsum traces of a red clay band were seen. This gypsum is again faulted against the south side of the outlier. (Fig. 19). Associated obscurely with the gypsum are the usual gray and greenish shales and thick clays, with flaggy beds crowded with nummulites, towards the northern limestone, which, together with the clays, has a high inverted dip to the southward, and in a deep ravine crossing this limestone at a waterfall south of Maylookilla (Mélúkílla) red clays are again seen between the nummulitic limestone and nummulitic clays. Here, too, the limestone is faulted, so as to resemble a deep synclinal curve as shown in the sketch. Fig. 20. Sketch at water-fall south of Maylookilla (Mélúkílla).

Gypsum and other rocks.

Quasi-contortion.

a. Greenish clays and calcareous bands. *b.* Crushed red clay. *c.* Nummulitic, shaly limestones. *d.* Solid nummulitic limestone (4). *e.* Tertiary sandstones (5) much concealed by débris. *f.* Strong nummulitic limestones (4). *g.* Tertiary sandstones (5). *h.* Red clay.

Unless the limestone *f* be an entirely accidental and different band from that at *d* (which could not be proved), there must be here a faulted displacement in a vertical direction of very much greater amount than the distance between the two limestone ribs, which would admit of about 300 feet of the tertiary sandstones, &c., intervening. These latter are inverted, and the clue which they might give to the arrangement of the whole is lost in consequence of their being much concealed by débris. The occurrence of the red clay at *b* may indicate another parallel fault, and a pocket of very similar red clays at the foot of the waterfall at *h*, close to the nummulitic limestone, is too obscurely seen to admit of its being referred decisively to either the tertiary sandstone series or the supra-gypseous red zone.

A couple of miles eastward of Soortung (Súrtung) in the neighbourhood of the rock-salt locality of that name, complexities also exist, faulting and disturbance

Complexities at Soorthung salt locality.

rendering the arrangement obscure, still a tendency to an anticlinal structure may be observed. The clays of the gypseous series appear to be locally very thick, though much wasted, and the gypsum is most largely developed on the south side of the original curve or arch. Fig. 21 shows this section at Soortung (Súrtung) salt locality west by south from Teeree (Tírí).

1. Salt. 2. Greenish and gray clays. 3. Thick gypsum bands. 4. Brown sandstones and earthy limestones and shales with bands of gypsum and of purple or red clay. 5. Shaly and compact nummulitic limestones. 6. Tertiary sandstones, clays, &c. Three feet red clay bands to south of section. R. Thin red clay north of section. G. Thin band of gypsum. F.F.F. Apparent faults.

Nummulitic limestone associated with gypsum.

Ascending to the first northern brow of the range here, over curved and tilted tertiary sandstone, some thin, shaly, and harder limestone of the nummulitic series crops out along the summit of the ridge, and turning over faces its southern side, sloping into the valley. Just at the northern outcrop at one spot, a little gypsum was found beneath the limestone, and as if overlying some red clay. Towards the top of the outcrop very dolomitic-looking limestone, succeeded apparently the more shaly kind, and then overlying this with a dip of 30° to the south came a glistening saccharoid gray sandstone succeeded by red clay and purple sandstones, then by sandy clay with masses of white, opaque, gypsum in it, all over laid by 80 or 100 feet of dull, earthy, calcareous and sandy rock, passing in places into hard, whitish and gray calcareous sandstone, coarse calcareous sandstone and limestone in places.

Lower Nummulitics.

These rocks soon change from their southerly dip, forming a synclinal curve as shown at 4 in the section, but in the southern outcrop of this synclinal the section is not at all the same as that to the north.

Gypsum in this group.

The calcareous and sandy rocks last mentioned form the upper edge of this scarp, resting upon 50 feet of whitish, soft, gypsum, beneath which is a talus of 200 feet or so chiefly formed of greenish-gray clays.

There seem to be different beds of gypsum among the sandstones of this escarpment, one evidently subsided portion of the hill exposing the following succession :—

	Feet.
5.—Light coloured clays	
4.—Gypsum	6
3.—Calcarcous sandstone	8
2.—Sandstones and clays	50
1.—Greenish clays	70

Limestone and gypsum both belonging to one group.

Mere faulting along the face of the nummulitic limestone at the northern side of the section appears insufficient to account for the relations here, and yet the occurrence of these gypsum bands close to the limestone and among the sandy and earthy beds, elsewhere below it, together with the occurrence of nummulitic layers in the greenish clays down in the khud immediately to the west, would seem to point strongly to the important fact of the limestone and gypsum series both forming parts of the same nummulitic group.

Salt locality.

The ground about the salt sepoys' (sipáhis) boorj or chowkí at the foot of the escarpment just now described is all of clay, clay debrís, and fragments of the local rocks, some deep circular openings at the heads of streams running to the eastward, exposing from 50 to 70 feet of this heading over the gray rock-salt which was from appearances estimated to have a depth of 100 feet, and an uncertain dip to the west and north-west.

Cap of the lower nummulitic series.

A high tabular hill to the eastward overlooking the salt locality and salt chowkí shows the sandstones and purple or red clays of the synclinal north of the chowkí forming a nearly horizontal cap to the hill, the lower slopes of which are composed chiefly of the clays beneath.

Gypsum and limestone of the southern side of range. Inversion.

To the southward of the chowkí a long rib of gypsum stretches in the direction of the range, traces of red clay occurring both along its northern and southern sides, the former between it and the clays associated

with the salt, the latter intervening between the gypsum rib and the nummulitic limestone of the southern side of the ellipsoid which, like that to the north, is inclined the wrong way, dipping to the north, or is vertical or disturbed along the inner side of the southern ridge, the outer slopes of this being formed, generally up to the crest, by the lower beds of the tertiary sandstone and clay series.

Interior of range to east.

To the east of this Soortung (Súrtung) salt locality for about three miles the ridges forming the opposite sides of the ellipsoid diverge, leaving a wide space between covered with gypsum and débris of the accompanying clays, the nummulitic limestones as usual forming the crests of the outer ridges, or reaching high up on their inner sides, and traces of the usual red clay zone being observable between the limestone and the gypsum within.

Merándí pathway section.

Where the Merándí (Mírándí) short cut or bridle-path from Teeree (Tírí) to Totukhí crosses the range, the true relations of the rocks begin to become more apparent. The lower tertiary sandstones and clays at a short distance south of the Teeree (Tírí) river dip northward at high angles up to 60°. Further southward up the ascent they become contorted, and are at last faulted against the nummulitic limestone, having patches resting upon it, and the junction with the limestone here at one spot presenting the appearance seen in Fig. 22, which shews the junction of limestone and tertiary sandstone, Merándí pathway.

Fault.

1. Contorted purplish-gray sandstones and purple clays. 2. Contorted and crushed nummulitic limestone.

Nummulitic.

Where the path gains the first summit, the nummulitic limestone and shales are seen to form an irregular and disturbed band undulating along the crest, sending out a short narrow projection among the sandstones to the north-east, while to the eastward they pass gently and conformably beneath the latter rocks. A few paces southward near a small tank the limestones are much disturbed, and a few beds

Red clay zone.

of the sandstones are brought in by faults, the little tank itself being upon the bright-red clays usually found just beneath the nummulitic limestone. A rising ground above the path here exhibits interstratifications of the gypsum and sparkling gray sandstones of the interior hills undulating over the ground, the gypsum, as usual, being apparently thin at its northern exposures and more largely developed towards the southern side of the ellipsoid. Proceeding still to the southward over this undulating gypseous and sandstone series the red clays are again met with at the foot of a long east and west escarpment rising above all the neighbouring hills, formed mainly of the hard *alveolina* and nummulitic limestone dipping at low angles and forming a bold curve as it descends to the southward, quite conformably overlaid by the tertiary sandstones and clays.

Gypsum and sandstone of lower nummulitics again interstratified.

Alveolina limestone.

This outcrop of the limestone turns pretty sharply to the south, exposing a fine section, where it overlooks the gypsum towards the southern side of the exposure of the interior of the range, the gypsum being here much more developed and deeply cut through, sometimes leaving natural bridges over the mountain stream close to the path. Gray clays are also here associated with it, but though the stratification is in places plainly seen the general relations are obscure, and the ground is much covered with gypseous débris.

Southern part of section.

The section in the portion of the limestone escarpment presented to the westward shows the following succession :—

		Natural order, beds dipping south at low angles.	Feet.
Tertiary sandstones, 'Murree beds' ...	8.	Purple sandstone, tertiary sandstone series ...	60
	7.	Deep purple sandstone and reddish purple clays do.	
Nummulitic ...	6.	Hard *alveolina* limestone	15
	5.	Thin, flaggy, limestone and clay	35
	4.	Greenish clay	20
	3.	Dark-gray limestone	5
	2.	Green clay with layers of sandstone	20
	1.	Deep and bright-red clay, with some flaggy, harder bands containing *nummulites*, &c.: thickness not seen, but 50 to 100 feet exposed in the vicinity.	

Fig. 23 shows this section near the Merándí path from Teeree (Tírí) to Totukhí, about three miles.

2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone and clay. F. Fault.

Nummulitic bands in the red zone.

The red clay zone, as seen at the southern part of this section, contains some hard gray sandstone layers and earthy calcareous bands with *nummulites* and other fossils, these layers being sometimes ripple-marked; some purple flaggy beds also occur, and layers of this red clay and of gypsum alternate near the junction of the two groups as if to unite the gypseous series with the overlying nummulitic rocks.

Sharp inversion.

The whole section so steadily and plainly exposed beneath the tertiary sandstone capping the limestone in the above section becomes sharply reversed to the southwards near where the Merándí pathway issues through a narrow gorge cut in the nummulitic limestone, here pushed over so as to incline to the northward at 50°.

Salt locality.

On the east side of the pathway before it leaves the gypsum, which is in this neighbourhood intensely contorted, and in the middle of a bank of gypseous rubble, there is a small exposure of rock-salt purposely concealed in the left bank of the stream which makes its exit through the gorge just mentioned, and which near the place leaves upon the stones in its bed a thick incrustation of salt.

Tertiary sandstones, &c.

South of the Little Pass, the tertiary sandstones at first dip northwards with the limestone, being very calcareous for 4 or 5 feet at the junction, but further out are inclined both ways at high angles towards a synclinal axis; another synclinal occurs further on, and between the two a fine anticlinal curve is seen in the adjacent spur to the west.

At a little distance from the hills, the purple sandstones and red clays resting upon the limestone high up on the hills, as shown in the

section, may be traced curving round the crushed and inverted fold in this limestone and passing downwards so as to underlie it in the way represented.

Neighbourhood of Totukhí tertiary sandstones.

The part of the Bahádur Khél valley near Totukhí lies high, separating the waters of the Teeree (Tírí) valley streams from those of the Kurshru Algud, and is rocky, the tertiary sandstones being set on edge with a high dip to the south where not vertical. The rocks are as usual gray sandstones and red clays of a higher place in the series than those nearer the hills, and showing less of red or purple colour, besides which the soft gray sandstones occasionally contain scattered pebbles of quartzite or conglomeratic strings.

South of Teeree, instructive sections.

Exactly to the south of the village of Teeree (Tírí), and to the south by east, the sections are very instructive as to the true relations of the rocks. The bold curves which these form may be seen from long distances on the northern flanks of the range, and on closer inspection the conformity of the groups at least down to the gypsum, which is generally more or less obscure, is as clear as their arrangement is in other places complex. The section seen is as shown in Fig. 24, the curves overarching a space of nearly a mile in breadth :—

2. Gypseous series. 3. Greenish clay. 4. Red clay zone. 5. Nummulitic limestone. 6. Tertiary sandstone, &c.

5	8. Gray and purple sandstones.		
	7. Reddish purple clays and sandstones with bone beds. Clay bands numerous.		
			Feet.
4	6. *Alveolina* limestone	... ...	100
	5. Shaly limestone	... ...	100
	4. Greenish and whitish marly clays chiefly	... ...	50
	3. Blood-red clays (thick here)	... ...	200 ?
	2. Green clays (a few feet).		
	1. Gypsum and clays, very thick, unknown amount in continuation of the sandstone and gypseous series, 1 in Figure.		

By carrying this section southward over the hills, it would traverse the continuation of the limestone and overlying sandstone of the

southern part of the foregoing Merándí section, and the anticlinal character of the whole range would at once become apparent. Facts like these in the arrangement of the rocks are worth notice, both because of their rarity and their importance in fixing the true relations of the complicated appearances to be found so often among the rocks of the country.

Alveolina limestone: lower tertiary: concretion band, bones, &c.

The uppermost beds of the limestone are of the lumpy, hard *alveolina*-bearing kind so commonly found just at the junction with the tertiary sandstones, and the lowest beds of these at this place include besides a peculiar concretionary band, the nodules of which range about the size of walnuts and under, some pseudo-conglomeratic calcareous layers containing bones smooth, polished, fluted and pointed, reptilian teeth, crocodilian scutes, and tortoise plates abundantly, but in a fragmentary state.

Contortion at Burburra boorj.

The regular anticlinal just now noticed is not maintained for any distance eastwards, an instance to the contrary occurring southward of the village of Hossain Bándá at the Burburra boorj or salt chowkí on the northern crest of the hills; here from the ridge a little to the westward the nummulitic limestones and the sandstones above them are again seen inverted as in Fig. 25.

3. Red clay. 4. Nummulitic limestone, here only 50 feet. 5. Tertiary sandstone, &c.
A calcareous gravelly bed at the junction with the limestone.

Serappah or Burburra salt locality.

This Burburra boorj overlooks to the southward one of the largest salt exposures in the country after that of Bahádur Khél. It is known as the Serappah or Burburra-drung. Here the whole of the interior space between the outer ridges of the range is evidently much disturbed from slippage and subsidence of the soft rocks; in consequence of the existence and removal of the salt beneath, great patches of gypsum extend over the ground, and gray and

greenish clays are, as usual, obscurely intercalated with it, this gypsum not being traceable with any continuity throughout the tract.

Towards the fringing nummulitic zone north and southwards red clays are strongly seen, and in one of the deep gullies opening to the south, under a mass of reddish coloured clay-débris, the dark rock-salt is horizontally exposed for nearly half a mile, chiefly towards the bottom of the ravine on both sides, but rising in the banks and side nallahs high up nearly to the general surface of the hilly ground. Its total thickness is nowhere visible, but must exceed 100, while it may be more than 200 feet.

Black gypsum.

At one spot towards the head of the stream, a little black gypsum and black shale appeared at the base of a salt cliff, but as this is usually the character of the gypsum just overlying the salt, or even higher up near the top of the gypsum itself, and as the place was much overrun with detritus, it would be unsafe to draw conclusions from an unsatisfactory exposure of the kind which might have slipped bodily from above, nor could any results be arrived at from the clay in contact with the salt now occupying a place which might easily have formerly been filled by gypsum or the gypseous series. Gypsum is seen in quantities approaching the spot from both sides, but near the ravines it greatly gives place to débris.

North side of section most regular.

Notwithstanding the recurvature of the limestone to the north as shown in Fig. 25, this northern side of the section presents more of the original anticlinal arrangement than the succession to the south, the tertiary sandstones dipping steadily into the Teeree (Tírí) valley, while on the opposite side of the range these tertiary sandstones and the nummulitic limestones are either quite vertical or slightly inverted.

Glen to east of Serappah.

The next glen eastward from Serappah opens to the northward, and though only half a mile distant again exhibits extreme complication, much faulting, and a locally large development of the red clay zone, while the great mass of salt

seen at Serappah is not exposed. The section seen when approaching from the north is as shown in Fig. 26.—

2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone and clays. F. Faults.

5.	Gray sandstones, purplish sandstones, and purplish-red clays, psuedo-conglomerates, purplish-gray clay at junction in one place, in another gray sandstone ...	part only.
4.	Hard *Alveolina* limestone	20 to 50 feet.
3.	Red clay zone, largely developed at one place ...	300 to 400 „
2.	Gypsum, stratified and unstratified, clays, &c., may be	400 or 500 „

Tertiary sandstones: nummulitic limestones: their contact conformable, but peculiar.

Entering this mountain glen behind the village of Khurree (Khurrí) Bándá the usual lower purplish and gray tertiary sandstones form open undulations, and in one spot a curvàture in these allows the nummulitic limestone to be seen, taking the ground in all directions. Somewhat within the glen a continuation of this limestone (*a*) appears as if faulted on its northern side, a small surface of the limestone being exposed in the centre of an anticlinal curve. At the contact the limestone is lumpy with interstices filled by purplish-gray clay similar to that of the adjacent bed above; this is succeeded by gravelly layers containing concretions and pebbles of bluish limestone and of sandstones similar to those in the immediate vicinity, the sandstone and limestone beds being quite parallel and conformable.

For two or three hundred yards up the stream, the ordinary gray sandstones and purple clays of the lower tertiary sandstone are much crushed and contorted, and then the northern nummulitic rim of the ellipsoid (*b*) is reached. This limestone is of the hard *alveolina* kind, and is inverted, dipping south at 80°, the gray tertiary sandstone coming next above (but here underlying) it, having been apparently crushed along its surface in such a way that angular portions of the limestone were dragged from their places and gray sandstone forced into these cavities to a depth from the surface of the limestone which in one place measured 10 feet. The fractures of the limestone are all angular, and

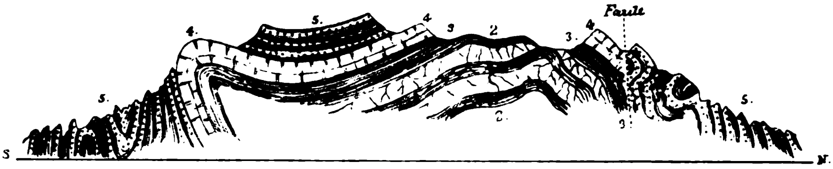


Fig 23. Section near Merandi path from Tiri to Totukhi

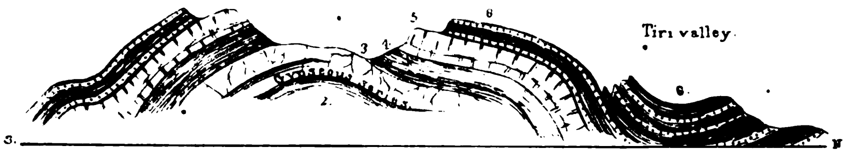


Fig 24. Section Southward of Tiri Village

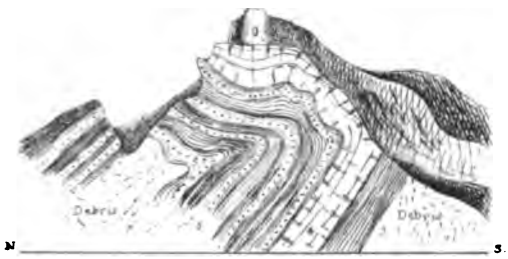


Fig. 25. Contortion at Burburra boorj.

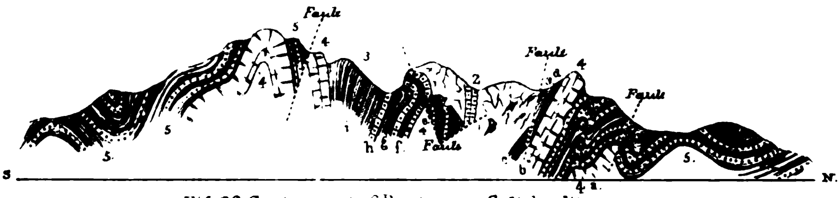


Fig.26. Section east of Burburra Salt locality.

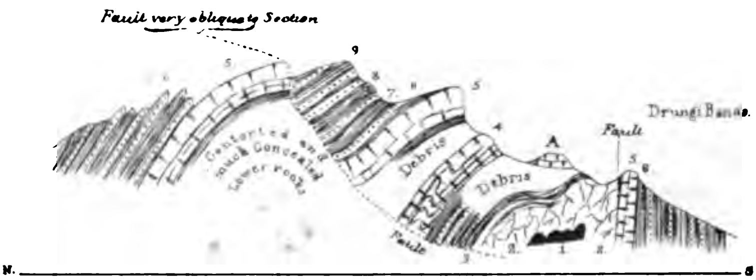


Fig 27. Section behind Drungi Banda

present no trace of erosion, nor are there any signs that the sandstone was deposited in these irregular hollows. The limestone here seems irregular, but thinner than in most other places, not being more than from 20 to 50 feet in thickness. On its inner side some greenish clays are in junction with it in the stream bed (*c*), but on the height above the left bank of this (*d*) red clays occur in their natural place next to the limestone. Further up the stream, contorted and obscure masses of gypsum and greenish clay, the latter often wedged apparently among the former, are seen filling up the interior portion of the range. At one spot where the stream crosses a mass of the gypsum, the latter is so deeply eaten into that it becomes impracticable to keep to the river bed, and here a small mass of the tertiary gray sandstones (*e*) and red clays appears to have slipped from somewhere above into the middle of the gypsum. Just beyond this to the southward the gypsum (*f*) is plainly stratified, vertical below, but bent over above as shown in the figure, and is in close contact with 35 feet of greenish clay (*g*), also vertical. Next beyond these in the same direction is a 5-foot band of hard gypsum (*h*), beyond which comes a mass of deep red clays (*i*) with green and purple sandy layers or somewhat flaggy bands, all on edge and dipping at high angles to the south, their thickness being estimated at not less than 350 feet. The surface formed of these rises towards the southern crest of the range where the nummulitic limestone again appears, but in contorted and broken exposures, among the tertiary sandstones and clays of this side of the ellipsoid.

Red clay zone.

Faulted inlier of sandstone.

Junction of red clay and gypsum.

From the high ground here eastward the range declines to its termination south of Bándá Serai on the Kohát road, the crest of the ridge being formed of the tertiary sandstones, while below it to the north the nummulitic limestones of both sides of the ellipsoid unite, forming a single anticlinal curve, somewhat broken and disturbed along its northern

Termination of range near Bándá Serai anticlinal.

side, but seen to take the ground nosing to the eastward and consecutively enfolded by the sandstone and clay series, where the Kohát and Bánnú old road has been abandoned for a better line curving round the end of the range close to the south bank of the Teeree (Tírí) Tauí river.

Complex character of the whole range.

The whole of this range from Manzullí to Bándá, apparently in consequence of the large development of gypsum and soft rocks within the limestone-crested ridges, and the great pressure exerted upon them, presents some of the most complex ground in the district. From the details given, it will be seen that in many places it is difficult to conceive what forms eroded or denuded portions of the sections may have taken. It will be also evident that without the existence of the few sections in which the rocks are normally superposed south of Teeree (Tírí), and the evidence afforded by the anticlinal south of Bándá, or similar sections elsewhere, the task of reducing such a mass of contradictory confusion to anything like proper order would be well nigh hopeless.

4.—*The ridge from Bándá Serai to the Jatta ellipsoid.*

Ridge from Bándá eastward.

This ridge, which has between the points above named a summit elevation of 3,198 feet (the correction in the note upon the Trans-Indus Frontier map being added) is little less complicated than the more extended range just described.

The rocks are broken and displaced by faults, yet remnants of a former ellipsoid structure are to be recognised in the narrow and fragmentary bands of the nummulitic limestone along its southern or scarped side.

Anticlinal ending of the nummulitic limestone.

At the western end near Bándá Serai and military post, the nummulitic limestone which sheets its northern slopes may be seen making a half turn to come round and join that to the south, but the curve has hardly reached the axis of the anticlinal till it is suddenly interrupted apparently by a strike fault,

leaving the southern slopes open to expose the gypsum and other soft strata of the interior of the range, where these are not overrun by limestone and other débris from the outcrop.

Gypsum and red clay zone.

Just above the road westward from the Serai some of the gypsum is seen, and some contorted liver-coloured thin sandstones forming part of the red clay zone. The latter, too, may be traced at intervals just below the outcrop of the limestone on the crest of the hill, this feature being formed by the hard yellowish *Alveolina* limestone or marble beds.

Salt exposures.

Within a mile to the east of the Serai some small exposures of the rock-salt occur among black, earthy gypsum and red clay, purple sandstone, and limestone débris, in the banks of streamlets on the southern side of the ridge, but the sections are so overrun and concealed that nothing of the structure is observable. Near this place narrow vertical exposures of the nummulitic limestone commence, and these continue more or less visible to beyond the village of Drungí Bándá at the foot of the ridge where the Teeree (Tírí) river makes a sharp S-like turn in its easterly course.

Drungí Bándá salt locality.

Salt quarries are said to have been formerly worked behind this village (hence its name), and on entering the little valley in which they are situated on the southern slopes of the ridge, purple, greenish and gray sandstones and purple clays are found perfectly vertical. Between these and the southern rib of *Alveolina* limestone, which is also quite vertical, is a zone of redder clays than usual among these rocks with gray sandstone layers interspersed. The limestone itself is thinner here than usual, the whole of the beds not being apparently present. Just behind the limestone is a mass of gray and black gypsum and black bituminous alum shale, any stratification in which appears to undulate to the northwards. Low down in this gypseous mass, or more likely just below it, blackish-gray rock-salt is seen for a thickness of 10 or 15 feet on the left bank of the stream and close to its level. The salt appears

Limestone, thin: black gypsum: alum shale.

also to dip to the north at a low angle, and may very probably be but the upper portion of a thick deposit, as seen elsewhere. The black bitumi-

Bituminous shale and sulphurous springs.

nous shales close by smell strongly of petroleum, and sulphurous springs issuing from them are saline and milky-looking, but leave a black deposit on the stream bed, contrasting strongly with the snow-white salt incrustation on the drier places.

Immediately north of the gypseous mass some red clays are seen, succeeded by variegated sandstones and nummulitic limestones having high and contorted dips to the north as follows :—

7. Red clay and green clay mass, all crushed and unconformably overlaid by a displaced mass of gypsum close to a large fault.

	Fault.	Feet.
6.	Hard, cherty limestone and gray shales exposed with high and distorted dip to north for	100
5.	Variegated yellow and purple sandstone ... }	50
4.	Coarse purple sandstone ... ... }	
3.	Red clay, small exposure.	
2.	Black and gray gypsum, and bituminous shales	?
1.	Rock-salt dark-gray and blackish, seen	15

Details of section.

The red and green clays No. 7 appear not to belong to the succession seen here, but more probably represent some part of the infra-nummulitic limestone red clay zone. The lower part of the limestone No. 5 has coarsely oolitic-looking portions made up of small foraminiferous-looking organisms, sometimes like tiny

Fossils of nummulitic limestone.

nummulites. Above these long *turritella*-like shells occur, and small spherical bodies covered with punctures. In a gray shale band here, and in a limestone layer just above it, small *nummulites*, spiral shells, and fragments of bivalves occur. Next above these, a dark compact thin oolitic-looking layer encloses fragments of oysters, and the uppermost layer of all is highly fossiliferous, containing many of the common *gastropodous* and *bivalve* shells of the nummulitic limestone. Tracing this zone up the hill side a considerable interval covered with sloping detritus and probably occupied by soft beds

is seen, and then the stronger *alveolina* beds crop out forming the high summits of the ridge.

Fault.

From the place of No. 6 in the above section a strong fault starts to the north-east by north obliquely across the ridge, throwing the limestone last mentioned to the southward, and introducing a mass of the tertiary sandstone series on the outcrop side of the continuation of the nummulitic limestone sheeting the northern side of the ridge. Fig. 27 gives the section behind Drungí Bándá.

1. Rock-salt. 2. Gypseous series. 3. Clay and sandstones; (section given above). 4. Nummulitic limestone and shale. 5. Nummulitic *alveolina* limestone. 6. Red clay. 7. Purple and gray sandstone and clay. 8. Purple clay and dark-gray sandstone. 9. Gray sandstone and red clays. 6, 7, 8, 9. Tertiary sandstone series. F. Fault?

Eastern part of ridge.

From this place eastwards to the junction of the ridge with the Jatta hills north of Zunuk the general arrangement of the rocks is the same as that of the southern part of the above section, except that the southern band of limestone is less regular, or ascends somewhat higher on the hills and caps one of them as at A in the foregoing figure.

Just before the ridge adjoins the Jatta hills, its crest alone is occupied by the limestone, which is slightly faulted in an east and west direction, the tertiary sandstone to the south rising high upon the ridge, and the lower purple and bone beds with shark's teeth, &c., of the same series entering as a synclinal curve the valley between this ridge and the western end of the Jatta ellipsoid.

Low ground on each side.

The open ground northward of this ridge is less rocky than that to the south, where the banks of the Teeree Towey (Tírí Tauí) and the ground above them both expose the gray and red vertical or inclined, alternating red clays and gray sandstones of the lower tertiary sandstone series.

5.—*The Nummulitic Ellipsoid of Jattá.*

Another anticlinal axis.

This ridgy feature is connected with the range just now described, but evidently owes its origin to a different anticlinal axis. It is about seven miles in length by one in width, and its harder strata, though faulted both longitudinally and across the strike, have decidedly anticlinal terminations at either end of the feature. The softer gypsum and rock-salt forming the interior of the curve are largely exposed, but the outer rim of limestone is incomplete, having been cut out by a fault at the valley of the Ismaíl Khél river on the northern side of the ellipse.

Limestone disturbed.

Towards the southern side of this at both ends the superficial exposure of the nummulitic limestone is largest, but between these points this limestone is on edge, showing many signs of disturbance, or almost disappearing owing to dislocation.

Black gypsum and alum shales.

Anticlinal appearance of rock-salt.

The tertiary sandstones surrounding and enfolding the limestone are of the same character as those usually forming the lower part of this series. The red clay band just beneath the limestone does not appear to have the thickness it sometimes displays, but is seen in sundry places, and the gypsum below is of the common dull gray and white kinds passing in places into very dark or a black bituminous rock, associated with which are alum shales. Below all the salt appears to conform to the general anticlinal structure; it is of the usual gray colour, but in certain localities near the top is sufficiently bituminous to smell strongly of petroleum, a scent which may also be perceived slightly in some of the apparently purest rock-salt of the quarries at Jatta.

North side of ellipsoid.

Near the road from Ismaíl Khél to these quarries and the Ismaíl Khél river up to the slopes of the hills, softish, gray and purple sandstones and purple clays with some very red zones of the latter are, as a rule, nearly vertical, dipping one

way or the other a little from east and west lines of strike. A band of purple color runs along the side of the hills, and between this and the limestone the clays have a redder tinge.

In the gorge of a stream due north from the quarries, this red band underlies the nummulitic limestone at an angle of 70,° both being inverted. The limestone here is about 80 to 100 feet in thickness, and consists of *Alveolina* limestone outside, hard, dark, and flaggy limestone with one cherty band near the centre, and more shaly alternations with thin oyster-bearing bands towards the south or lower part of the group. In the hard dark limestone, sections (presumably of long *gastropodous* shells) of the forms shown in Fig. 28 are not unfrequent, and have also been observed in other neighbouring parts of the district: the figures are about natural size. Just inside the limestone band, a considerable quantity of very red clay occurs, in which there are purple sandstone or flaggy layers; south of this clay and within the belts formed by it and the limestone, the gypsum and gypseous clays cover the ground, being irregularly and unequally spread over it, sometimes in quantity though of uncertain thickness, and sometimes as close to the highest of the salt quarries, apparently absent, or but poorly represented. A projecting part of the escarpment here presents the following section, but the upper zones were not within reach of measurement:—

Fossil shell sections in the limestone.

Gypseous series within the limestone border.

Section.

(Arrangement nearly horizontal).

5.	Nummulitic limestone, a remnant.	Ft.
4.	Red clay zone	25
3.	Greenish clays (*Sheenkoura*)	6
2.	Dark gray salt, bituminous for 2 feet at top ...	10
1.	Good gray salt	50

Along with No. 3 at a little distance was a 10-foot band of greenish-gray gypsum.

Black shale.

To the northward of the salt chowkí or boorj, on the rising ground there, covered with gypsum and gypseous débris, the former contains a black carbonaceous-looking

shaly layer 10 feet thick, not traceable far, and dipping south at 40°. It looks like alum shale, but has no bituminous or sulphurous smell.

Rock-salt said to have been worked through.

The salt in these Jatta quarries seems disposed in a thick zone, partaking of the general anticlinal structure of the place and rising to the westward. In this the whole of the quarries might be situated within a thickness of from 200 to 300 feet if the salt were extended horizontally. There are no means of estimating the true thickness of such a zone, but quarries at different elevations show a depth of 15 or 40 or 60 feet of solid salt. In one of these quarries, and that one of the lower ones, though not the lowest, the single case in the whole district of their having ever, even by repute, been penetrated came to notice. Here at the 'Thathara quarry' a '*Drungwal*' or quarryman stated that at one time long ago when the quarry face had not been worked back so far north, a bottom to the salt had been found, and that *Skeenkoura* (gray gypseous clay) occurred beneath. The statement, however, seemed doubtful, and even if true, an older working of the kind described in the appendix may only have been reached, and not the true base of the salt deposit, so that the workman's story may be taken with a considerable grain of the adjacent mineral.

Salt taking ground to eastward.

The whole of the salt appears to take the ground to the eastward, and all the quarries and exposures occur within a less space than one mile in an east and west direction. At a short distance eastward, after passing the last quarry, there are seen what look like two old pits or excavations in some black alum shale overlaid by impure gypsum. The shale seemed to have become partially burnt spontaneously; it contained iron pyrites, much iron oxide, and some coaly layers. One band in the clay was crowded with small nummulitic shaped bodies composed of gypsum. The whole was disturbed, and the dip at one place shifted to the west of north at from 20° to 40°, the thickness exposed being about 15 feet. The

Salt, alum shale, and gypsum smelling of petroleum.

gypsum close by smelled strongly of petroleum, as did also some of the clearest salt far below the dark bituminous upper layer.

Petroleum also in other dark shales.

What may have been fragmentary portions of this or similar bands of dark carbonaceous-looking and bituminous clay were seen also in connexion with the salt of those quarries on the northern side of the ellipsoid. One of these overlying a corner of the Thathara quarry absolutely stank of petroleum, and in this and other quarries near it and further west cracks in the salt had been filled either with such bituminous clay or with a sandy deposit sometimes evidently washed in from above. Other fragmentary bands of alum or bituminous shale and petroleum-smelling gypsum occur to the eastward near where the Ismaîl Khél river crosses the ellipsoid to join the Tïrí Tauí. The diffusion of petroleum through the salt and gypsum here is remarkable.

Confusion close to southern border.

To the southward of the alum shale pits there is at one place much confusion close to the southern rib of the limestone, red clay, greenish clays, gypsum, and the nummulitic limestone being jumbled together as if portions of the interior rocks had at one time slipped or been pushed outwards across the limestone. At a short distance, however, the series is seen nearly vertical, but in proper order, the tertiary sandstones outside, then about 50 or 60 feet of the nummulitic limestone, behind which are greenish clays or shales in contact with red clays thicker than the limestone, and containing purple sandstones. At the northern or lower side, the gypsum and gypseous débris of the interior adjoin the latter, and further relations are lost.

Nummulitic limestone cut out by fault; and shells in tertiary lower sandstones.

At that part of the ellipsoid where the northern rim of nummulitic limestone is cut out, and the Ismaîl Khél river enters the gypsum, the junction of the tertiary sandstones and the faulted limestone is peculiar.

Fig. 29 shows this nummulitic limestone under cut by faults above the left bank of Ismaîl Khél river.

1. Gypseous series. 2, 3, 4. Nummulitic limestone. 5-14. Tertiary sandstone series.

Dip North 90° and less.

		Feet.
14.	Gray and green sandstones with purplish clays.	
13.	Purple sandstones and clays and pseudo-conglomerate.	
12.	Purplish-gray sandstones with a few bands of very red clay.	
11.	Dark purple sandstones	5
10.	Red clay	10
9.	Purple, flaggy sandstone with green blotches	2
8.	Thin-bedded, gravelly-looking, purple pseudo-conglomeratic or conglomeratic beds, limestone concretions, and fragments of yellow limestone with nummulites, bone fragments in base, thins out	8
7.	Hard, red, calcareous, flaggy shale	10

Shells.

In this is a narrow 9-inch layer (6) of calcareous nature crowded with imperfect casts of strongly-ribbed *bivalve shells* resembling some kinds of *Cardium or Cardita*, imperfectly preserved in white carbonate of lime; the only shells found in the tertiary sandstone series—

Fault.

		Feet.
6.	Compact *Alveolina* limestone wedging out of yellow or buff colour, fossils scarce	50
5.	Thin-bedded white and yellow limestone with *Nummulites*, *Alveolina*, *Cardita*, and other bivalves	15
4.	Gray, shaly, nummulitic limestone full of small *Nummulites* and in parts minute organisms giving the rock an oolitic look	20
	Room for some feet of soft beds? Red clays not seen.	
2.	Gray gypsum with dark or black large patches highly impregnated with petroleum or bitumen.	

The actual amount of underlay seen here bringing the vertical sandstones, &c., beneath the vertical limestone is very small, yet probably extends to the whole thickness of the limestone, 80 or 90 feet, as this is completely cut out, unless, indeed, there be another shift of the beds on the southern side of the limestone also where the red clays are not seen.

Fault, not unconformity.

Advocates for entire unconformity between the limestone and next newer beds, which the structure of this country has never been found to support, would probably

claim a case like this as corroborative of their view, and might do so with some reason, if a hollow only had here been excavated from the limestone surface, no other signs of disturbance affecting the neighbourhood. But the sudden disappearance of this limestone, elsewhere continuous, and the prevalence of faults at no great distance, leave an impartial observer little doubt that one of the many dislocations of the country has here taken place, resulting perhaps from extreme tension or even traction of highly convoluted beds unable to yield further to a contorting force that may have been accompanied by some amount of stretching effect.

Re-appearance of the limestone.

The limestone re-appears about half a mile to the eastward at a little distance from a rectangular bend in the stream, thence forming the northern side of the ellipsoid. Here, again, the shelly band in No. 5 of the above section re-appears, the fossils, however, being too obscure to give much hope of their determination.

Bozhá gorge: disturbance.

To the southward where the river leaves the gypsum and limestone by a rocky gorge near Bozhá Bándá the strata are also much disturbed; the southern rib of limestone, which half a mile to the west has a thickness of 50 or 60 feet, is here represented by only a few beds, and these on the left bank of the stream are inverted, inclined to the north and crushed over to the tertiary sandstone series, yet at a short distance may be traced higher up upon the hill overlooking the river on this side, recovering their position, and with the overlying sandstone beds assuming the southerly slope proper to that side of the anticlinal curve.

Gypsum again in nummulitic.

At this place, too, a mass of gypsum occurs in an unusual position within the lower nummulitic beds, and with much less regularity than is observable in the cases mentioned with regard to the intercalation of gypsum bands nearly in the same relative situation not far from where the meridian 71° crosses

the Manzullí and Bándá range (see page 110). Fig. 30 is a diagrammatic sketch of the structure seen on the left bank of the stream here.

13. Red clays and greenish-gray sandstones in thick alternate zones, more sandstone than clay.
12. Gray and purple sandstone and thin clay layers.
11. Red clay 15 feet in deep blackish purple thin sandstones.
10. Purple and gray sandstones and red clay.
9. Red clay much thicker in opposite bank of stream.

Crushed line of junction.

8. Hard dun *Alveolina* marble 6 to 20 feet.
7. Green clay.
6. Gray and white gypsum 15 to 20 feet.
5. Green clay, weathered olive.
4. Dark, cherty limestone with a flat-coiled shell like a *Planorbis solarium*, a couple of feet.
3. Dark-olive shaly clay, in places blackish.
2. Dull-red clay passing towards (1) into a purple, earthy, coarse sandstone with ferruginous base 1 foot thick.
1. Red clay.

The junction of the red clay No. 1 with the gypsum of the interior is concealed, but at a little distance to the northward the latter is seen overlying black alum shales, with thin pieces of bituminous, hard, black, flaggy limestone scattered over their surface, apparently derived from the dark bituminous parts of the adjacent gypsum. The alum shales, from their decayed state, are evidently pyritous, and native sulphur in small quantities was observed in their planes of division.

Eastern part of the ellipsoid.

To the eastward of this place the axis of the anticlinal seems to lie very much towards the north side of the ellipsoid, on the southern side of which a large mass of the tertiary sandstones has been apparently let in below the general surface of the nummulitic beds, and the contortions of the latter are seen to form strange elongated zigzags on the mountain side between the high tertiary ground and the eastern end of the hill.

Here the nummulitic limestone of both sides of these hills meets, forming a perfectly natural anticlinal U-shaped ending to the high ground from which the sandstones of the tertiary series slope into the neighbouring low ground.

Its eastern termination.

The sketch (Fig. 31) is intended to represent the positions of the various rocks looking from where the Ismaíl Khél river traverses the gypseous series westward.

1. Place of rock-salt. 2. Gypseous series, gypsum, clay, and alum shale. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone series. F. Faults.

To the eastward of the Jatta ellipsoid an open plain sloping to the Teeree Towey (Tírí Tauí) stretches out between this and the imperfect ellipsoid containing the quarries of Saya Malgheen (Séya Málgín), the distance between the two being about four and a half miles.

6.—*The imperfect ellipsoid of Saya (Séya) Malgheen (Málgín) (Salt quarries).*

The ellipsoid of Saya (Séya) is apparently formed on a continuation of the same anticlinal axis as that of Jatta, that is to say, they both occur in the same valley, and both lie between the same two longer ranges in such a manner as would suggest two upward undulations of one long anticlinal axis, there being no hills where the depression between would have carried the hard limestone rocks below the general level or incline forming locally the lowest limits of atmospheric denudation.

Continuation of Jatta anticlinal axis.

As usual in these features the ground is hilly, but little more than one ridge can be perceived, the southern side of the anticlinal having for the most part apparently disappeared in a fault coinciding very closely with the adjacent part of the Teeree Towey (Tírí Tauí) river bed, but where remnants are seen these are inverted.

Anticlinal imperfect.

Faults.

This is not the only fault affecting the configuration and structure of the ground, the northern nummulitic limestone rim being broken through in two conspicuous places as shown upon the map, besides adjacent smaller faults.

Anticlinal well seen at ends of ellipsoid.

But the main features of the structure are beautifully preserved at both ends of the ridge where the convex, smooth, hog-backed surfaces of the nummulitic limestones like the ends of an inverted canoe of huge dimensions take the ground, and are successively covered one over another by sheets of tertiary sandstone having the same form and a common axis of curvature. This is most evident at the western extremity of the hill, the anticlinal being continued for a long way by the sandstone series between two synclinal troughs, in which the successive beds may be traced each within the hollow of another. Further east other contortions supervene, but towards the Indus the strata become more steady as the succession rises to the newer sub-divisions of the sandstone series.

Tertiary lower sandstones.

The lower beds of the last named series rise high upon all sides of the Saya hills, except that towards the Towey river, where the slopes are of gypsum or gypseous débris overlying the salt. Between these two the nummulitic limestone forms all the higher crests and stronger features of the ground.

Bone beds.

In the very lowest of the sandstone beds close to the nummulitic limestones there are some highly fossiliferous layers full of bone fragments, such as ribs, terminations of large bones, parts of skulls, and not unfrequently reptilian teeth. These beds are well seen on the pathway by which the salt is carried to the depôt at Malgheen (Málgín). One slab close to the track contained, when the place was first visited, a large part of the rostrum and skull of a crocodile with several teeth (discovered by Dr. W. Waagen), but on a subsequent occasion this was searched for in vain, having probably been broken up in the interval, for many stones from these beds with the

appearance of having been freshly quarried were found collected near the spot as if with the intention of improving the road.

In the same layers with these bones, and having a somewhat wider vertical range than where previously observed, the same large thick-ribbed shell as was found near the Ismaîl Khél river again occurs, but in equally bad preservation.

Fossil timber.

Fossil exogenous (?) timber is also met with, sometimes in the lowest beds, sometimes higher up in the series, as in the valley between these Saya (Séya) hills and the ridge rising between them and Malgheen (Málgín).

Lower tertiary sandstones well seen.

In this and the neighbouring country, particularly to the north-eastward and the north, perhaps because the exposures of the lower rocks of this series are more largely displayed on the flanks of most of the hills, the difference between them and the newer beds of the sandstone series becomes very marked, the deep purple colour of the strong sandstones and the brighter red of the clay zones being very conspicuous, while to make the contrast stronger, thick zones of very green glauconitic-looking sandstone frequently occur among these lower rocks.

Their contact with the nummulitics.

The contact of these lower tertiary sandstones with the nummulitic limestone presents here no appearance of unconformity (any more than elsewhere), the very next bed to the limestone being highly calcareous, and containing numerous small nodules of brown hæmatite (as also observed beneath the limestone cap north of Kureerosum, (see page 94.)

It had long been suspected from the many slight differences observed in the various junctions of these groups that the newer one certainly, and possibly the older one also, followed no rigid and unvarying succession in detail, but that more naturally they were subject to a certain amount of lateral change, not, however, sufficient to remove or conceal their distinctive general characters. An instance in point occurs here,

where there is a very peculiar layer made up of small slightly flattened calcareous concretions exactly like, if not exactly the same as, one very often to be observed close to or just above the limestone, but at this place separated from it by about 100 feet of the lower tertiary sandstones, the bone beds and the layer containing both bones and shells. Hence it may be assumed with an amount of accuracy depending on the identity of this peculiar layer that the basal beds of the sandstone series, though generally contemporaneous, cannot be asserted to be strictly so within narrower limits than the time necessary for the deposition of a hundred feet of rocks.

Red zone.

The red clay zone below the limestone is seen, but can hardly be said to show itself strongly, here, and the whole of the interior of the ellipsoid forming the southern side of the ridge is enormously covered with gypseous and reddish-earthy débris partly re-arranged naturally into a recent gypseous rock or tufa, and partly artificially arranged by the long continued operations of the quarrymen in extracting the underlying salt, (see appendix).

Gypsum.

The gypsum presents the usual characters, being partially opaque and solid, white-gray or blotchy, and more frequently compact or granular than crystalline and translucent. The lower portion of it resting on the salt was found to be black and bituminous, and associated with some blackish clay like rotten alum shale, presenting carbonaceous, ferruginous, and gypseous appearances, and containing fragments of hard dark limestone derived from layers in the gypsum. Interstratified with dark coloured gypseous rock there was seen at one place a 2-foot layer of white salt, and in another as if lower than this, pale-gray, stony-looking gypsum, and a hard crystalline rock resembling a mixture of gypsum and limestone, in which were found some very small clear crystals of Anhydrite.

Salt and gypsum interstratified.

The stratification marked by these alternations was nearly horizontal, and being near the axis would coincide with the anticlinal

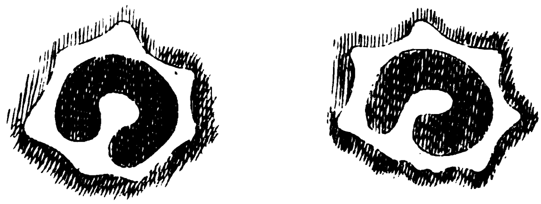


Fig. 28. Sections of Shells (ab^t Nat. size)

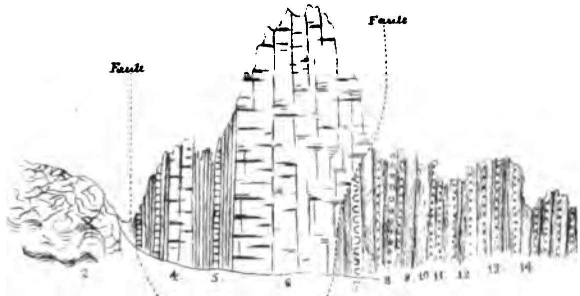


Fig 29. Nummulitic limestone [illegible] by fault above Ismailkhel River

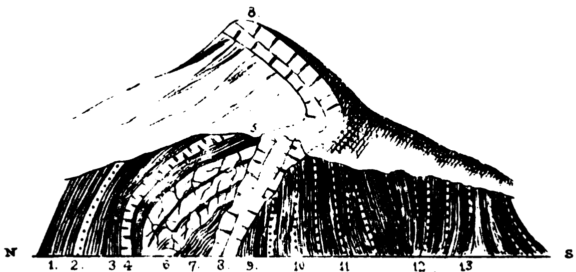


Fig. 30. Section on Ismailkhel River near B[illegible]ha Banda.

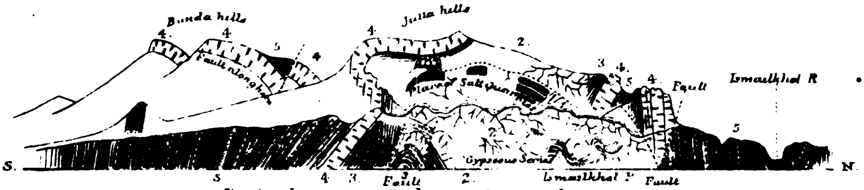


Fig 31. Jutta Hills looking Westward

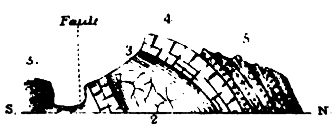


Fig 32. Kureerosum end.

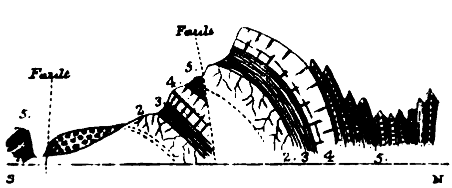


Fig. 33. West of Saya.

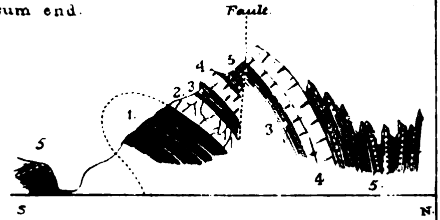


Fig. 34. East of Saya.

structure of the ground, as shown in the sections, Figs. 32, 33, and 34, of the Saya ellipsoid, (Malgín salt quarries) about one mile in extent, each.

1. Rock-salt. 2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstones. F. Faults.

Rock-salt.

The salt of this locality will be found referred to in the appendix; it is of the usual dark gray colour, and like that of other eastern localities, the upper part is in places somewhat bituminous near where it is in contact with the overlying black bituminous gypseous rock; from the situation of the quarries its thickness may be over 200 feet.

Boulder accumulation.

There is a rather large accumulation of boulders and débris along the foot of the hill west of Saya, now at a higher level than that at which the river runs, but which may nevertheless have been brought together by the transporting agency of this Teeree Towey (Tírí Tauí) stream in former times. It appears to be quite local.

Gold-washing.

A little further down the stream is the village of Zertungí on its right bank, at which gold was said to be washed from the sand of the stream during the rains, the practice having given the name to the place (zer), meaning gold in Pushtú or the language of this country, and (tunga), a kuss, khud, or ravine.

Fault in Teeree (Tírí) river.

The fault in the river here would seem to be considerable, and the tertiary sandstones on its southern bank appear to form undulations in the bottom of what had once been a narrow synclinal trough.

Contortions in its valley.

The contorted state of the beds extends for miles down the course of the Towey (Tauí), but before this reaches the Indus, steady sections are seen on each side rising upwards in the newer rocks of the series.

7.—*The hilly ranges and their neighbourhood from Bahádur Khél and Soordag (Súrdág) country to Nundrukkí and Hokurmí mountains.*

Form of ground.

Most of the hilly ground which has now to be noticed forms double or triple, often anticlinal, ridges sometimes with synclinal plateaux or other high ground, or deep valley, between the more elongated elevations. It first takes the character of a range towards the westward near Luttummer, where crossed by the Chungôsh river (called Chunghaze on the map), and here is formed of a central mass of tertiary sandstones and clays, rising to considerable heights, disposed in a wide synclinal curve or closely contorted between two remnants of smaller anticlinal curvatures, respectively north and south of the former at the edges of the range.

Ellipsoids.

The most northern of these anticlinals may be called the incomplete ellipsoid of Bahádur Khél, and the latter the still more imperfect one of Luttummer. Both occupy more or less, or coincide with, hilly ground trending in a direction generally parallel with the range. From the summits of this high ground the whole range may be seen to expand into a mass of nearly horizontally-bedded sandstone hills in the country of the Wazeeris (Wazíris) to the westward, rising conspicuously above which are the cliffs and pinnacles of an outlying patch of coarse conglomerates, known by the name of Káffir Kôt. (*)

Kaffir Kôt.

The section would doubtless be interesting and instructive, ascending through the whole series of the tertiary sandstones, but it is unfortunately, most of it, in forbidden ground. Directly south of Káffir Kôt almost every bed of the soft upper sandstones beneath that patch of

* Kaffír Kôt is simply a mass of conglomerate washed into perpendicular tower-like shapes by rain. One of these towers was ascended with great difficulty and descended with greater, there being literally nothing to hold on by. The whole of the range from Kaffír Kôt to the banks of the Koorum, some twenty-five miles to the west, is of the same formation. From information kindly supplied by Colonel H. C. Johnstone, Superintendent of the Punjab Frontier Survey, which quite corroborates the account given by the messengers sent the place (see pages 5 and 71).

conglomerate seemed to be visible in a southerly direction, with older beds coming out from beneath, as far as an anticlinal-looking limestone hill just beyond the meridian 70° 30′ east longitude.

Lower tertiary sandstones embracing Baháдur Khél anticlinal.

The lower part of this section comprising the usual gray and purplish beds of the basal part of the series overlies, curving and enfolding the western part of the Bahádur Khél anticlinal, where the nummulitic limestone may be seen conforming to the curves of the sandstones and followed within by the red clay zone intervening between the limestone and gypsum, the soft sandstone and shale or clay group with nummulites seen to the northward being absent here.

Inversion of limestone, &c.

Starting from this place the limestone on both sides of the anticlinal as far as the Kurshrú Algad (stream) south of Bahádur Khél is either much disturbed or vertical or inverted as usual, appearing to *overlie* the sandstones, &c., *beneath* which it passes to the west. Towards its base it contains some marly light coloured bands full of fossils, large *Lucina* and such bivalves in numbers; also *cones* and some other *gastropoda*. In other layers it also contains the large thin *rotalinæ* so characteristic of the 'Subathú' nummulitic bands in the Potwár; these, on the one hand, and the larger forms previously mentioned on the other, both combining to link together here and elsewhere certain of the characteristics of the Salt Range and of the Subáthú nummulitic types in a way which may have some weight towards the identification of all three as belonging to the same 'Subáthú' nummulitic period rather than forming different eocene stages.

Fossils.

Subáthú characters.

Red zone.

The red clays underlying the limestone display themselves most largely to the west where the axis of the anticlinal sinks, and the gypsum within occurs as a narrow zone, from the confused stratification of which little of the relations can be ascertained.

Inversion and crushing.

The inversion and crushing along the north side of the anticlinal would seem to have been accompanied by fracture in some places, though probably of no great amount, for a highly coloured red band in the tertiary clay and sandstones occupies the flanks of the hills, outside of which comes a greenish and gray band, chiefly of sandstones, not unlike those of Dungôte on

Greenish lower tertiary sandstones.

the Indus (eastward of Kálábágh), and these beds seem to be the same as those succeeding the limestone where the positions are more natural. In one place at about 300 yards outwards from the limestone a thin band of conglomerate occurs in the green sandstone, containing both quartzite and tertiary sandstone pebbles, a local feature which has been previously noted in the lower beds of the series.

Suppurrí salt locality.

One of the salt localities of the district occurs in the gypseous series of these hills just on its north side, and on the watershed between the Chungôsh and Kurshrú streams. The exposure of salt, said to be small, lay concealed by fallen masses of the gypsum, but a strong white incrustation of the mineral was seen to mark the spot.

Section.

As the western termination of the ellipsoid containing the largest salt exposure in the whole district, a cross section taken about two miles west of the Kurshrú gorge may be given to show the arrangement of the groups. Fig. 35 is a section across the hills, west-south-west of Bahádur Khél, about one mile in length.

1. Place of the salt a little to the west. 2. Gypsum. 3. Red clay zone with two sandstone layers at top. 4. Nummulitic limestone. 5. Tertiary sandstone series. F. Fault.

Bahádur Khél salt locality.

We come now to the salt field of Bahádur Khél containing its quarries, the latter forming a small feature of the place, while the salt at once attracts attention, stretching for four miles up the valley of a small stream, which runs westward into the Kurshrú defile. For four miles further eastward the salt is less exposed, but the nature of the ground shows its presence

with an average width throughout, often approaching and sometimes exceeding a quarter of a mile. It is not only in the bottom of this little valley that the naked salt is seen, for it also forms much of the sides and rises with two conspicuous hills 200 feet in height in the middle of the glen. The whole of these hills are exposed rock, and the rock is salt, except a small capping of craggy gypsum on top, which looks in places somewhat disturbed and greatly weathered (see frontispiece).

Aspect of the salt.

The aspect of all this gray rock-salt is peculiar, often dull and icy, with irregular darker patches or blotches, giving many of the beds a conglomeratic appearance, but which broken into are found to be perfectly clear and crystalline salt. In other places it has a blacker look, and thin muddy layers are not uncommon.

The stream in the valley is said to flow constantly and to be largely derived from springs; it is of course saturated brine running on a bed of but slightly concealed dark rock-salt strongly contrasting with the copious thick dendritic incrustation which almost entirely covers the stream, forming a surface of quite sufficient strength to support one's weight.

Complexity.

Notwithstanding that the exposure of the salt is so great, there are attendant circumstances giving a good deal of complexity to the relations chiefly on the south side of the salt tract, but, fortunately, these are specially clearly seen just at the western extremity of the latter in the Kurshrú Algud gorge, where two streams meet south-west of Bahádur Khél. As the section exposed here is so highly instructive regarding the arrangement of the groups, and shows the proper place of the salt, it will be well to describe it briefly (Fig. 36) before considering that taken across the larger development of the salt near the quarries to the east.

Kurshrú Algad section.

1. Rock-salt. 2. Gypseous series. 3. Red clay zone. 5. Nummulitic limestone. 6 & 7. Tertiary sandstone.

Anticlinal.

No.	North side.	Feet	Total	No.	South side.	Feet	Total
No. 7.	Red and gray beds sandstone and clay (crushed).		Part.	No. 7.	Red clay, sandy clay, and purplish-gray sandstone with two very red clayey zones, much crushed, 100 yards south of limestone.		Part.
No. 6.	Gray sandstone containing many lumps, blocks, pebbles, and irregular layers of dark-gray limestone.	35'	35'	No. 6.	Coarse, gravelly, loose sandstone quite local, regularly overlying the limestone, contains nummulitic débris; dies out.	5 to 7'	
					Gray and variegated clay with large lumpy spongiform limestone nodules.	4'	
No. 5.	Dark and pale-gray clay forming a thin layer overlying nearly white nummulitic limestone, fossiliferous	55'	67'	No. 5.	Rugged, lumpy, nummulitic limestone, with a hard gray band in the lower 30 feet, fossiliferous ...	70'	74'
	Two bands of red and yellow clay near bottom of above, one 4 feet, the lower thicker ...				Alternating limestone and shale with four red and yellow clay bands	4'	
	Gray clay or shale ...	10'					
	Thin band of hard nummulitic limestone ...						
	Gray clay, 3-foot band ...						
No. 3.	Purple and gray variegated clay	3'	228'	No. 3.	Purple and variegated slightly by green clay	15'	270'
	Red, marly clay containing a 2-foot 6-inch band of sandstone (4)				Red clay with sandy layers ...	39'	
					Coarse, purplish sandstone (4) ...	1'	
					Red clay	6'	
					Coarse purplish sandstone (4) ...	2'	
					Red clay with greenish layers below	207'	
No. 2.	Compact white gypsum ...	32'		No. 2.	Compact whitish gypsum ...	40'	

No. 1. Centre of anticlinal.—Gray and greenish clay with disturbed masses of gypsum and débris; also an exposure of rock-salt measuring 42 feet by 15 feet high; length between from gypsum to gypsum about 130 feet.

Details of section.

Descending this gorge from Bahádur Khél purplish-gray and red beds of the tertiary sandstone series are found at the northern side of the anticlinal dipping in inverted order southwards at 70°. They have a good deal of red clay intercalated as observed to the westward, and at their junction with the nummulitic limestone exhibit a broken, crushed, and disturbed appearance. The rock in contact with the latter is a gray sandstone with little trace of stratification, and containing both lumps and irregular layers of dark gray, compact limestone with few traces of fossils, and more rarely small white *alveolina* limestone pebbles, containing these forms. It contains also plant impressions, thin coaly strings, small bone fragments, and pyritous nodules.

The junction line is here, both as regards this sandstone and the nummulitic limestone, very irregular; at one place purple clay touching

the limestone, at another this sandstone with a thin dark-gray clay layer between. The surface of the uneven limestone does not look like one of erosion, and the appearance seems due to the effect of pressure upon rocks of unequal hardness.

Junction of limestone and sandstone.

The adjacent nummulitic limestone is of very light colour and contains numerous fossils. Interstratified with it are two red and yellowish clay bands (Fig. 37); the upper, 4 feet thick, and the lower, thicker like it, but containing lumpy calcareous nodules. Next to the strong band of limestone is a 3-foot layer of gray shale passing into the top of the red clay zone which is here marked by another 3-foot band of gray and purple variegated clay. For a great thickness below, this smooth, bright red

a. Nummulitic limestone. *b.* Gray sandstone. *c.* Red and gray sandstones and clays.

Sandstone layers in red clay zone.

clay occurs, with few traces of stratification nearly vertical and inclined somewhat to the south if anything. It is here and there covered with a white efflorescence, and not far from the top contains a well marked band, 2 feet 6 inches thick, of purple sandstone, in parts conglomeratic, from small quartzite pebbles.

Gypsum.

Below the red clay, in the middle of the section, are apparently two bands of nearly vertical gypsum enclosing between them a confused mass of greenish-gray clay or '*Sheenkoura*' with great detached blocks or masses of gypsum (one of which measured 30 feet across). Within this clay there is also exposed some of the rock-salt, its relations being very obscure, having little connexion with the arrangement of the clay and being partly concealed by débris. These two gypsum bands have quite the same character and nearly the same thickness, and, moreover, as the whole section is repeated on the south, it becomes evident that they once formed the sides of an anticlinal curve.

South side of section.

The red clay zone is some 40 or 50 feet thicker on the southern side of the axis than on the north, and the purple sand-stone band is here represented by two similar

layers. The uppermost portion of the zone, a band of pale purple clay, is also here proportionately thicker, and contains lumpy calcareous layers and nodules which increase upwards in quantity till they form the first bed of the nummulitic limestone.

Fossils are not seen in the lowest 4 feet of this limestone, where shales alternate with it, there being four red and yellow earthy beds among these, the lowest of which is the thinnest. A hard gray limestone band like that on the other side of the axis here occurs higher up in the group, and the upper portion of the latter is rugged and very lumpy nummulitic limestone with several of the usual fossils.

Southern junction of limestone and sandstone.

The junction beds of the tertiary sandstone here are somewhat unusual, the corrugated surface of the limestone being covered by 4 feet of gray and variegated clay, with large irregularly rounded limestone concretions or nodules. This is succeeded by a coarse, gravelly, loose sandstone, largely composed of nummulitic limestone débris, 5 to 7 feet thick, and following the clay and limestone stratification quite regularly. It is, however, quite local, and does not appear on the opposite bank of the stream. Over this come the red clays, sandy clays, and purplish or gray sandstones as usual. At the lower positions in this tertiary series the whole section is one of considerable interest, showing, as it does, the true structural relations of so many of the groups in a country where most of the appearances are apt to mislead.

Western anticlinal indications at Bahádur Khél salt locality.

With regard to the relations of the salt and clays and gypsum, which are so obscure in the centre of the section, much of the obscurity disappears on ascending from this gorge the little stream of the salt quarries valley, which unites with the Kurshrú Algud by a rocky fall in the tertiary sandstones at the southern side of the above sketch. Having reached the axial region, the salt, of which from 10 to 15 feet in height is exposed, is found horizontally arranged below gypsum, also horizontal, and some 15 feet of greenish clay intervening between the two.

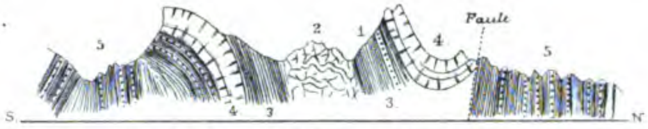


Fig. 35 Section W. SW. of Bahadurkhel

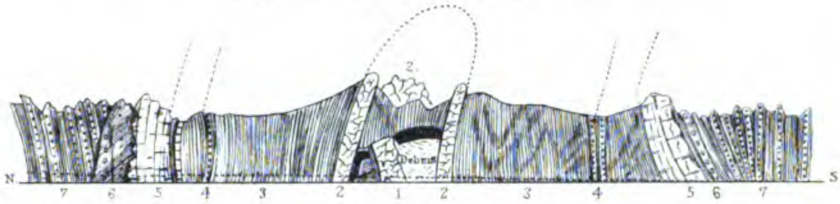


Fig. 36. Section on left Bank of Kurshru algud.

Fig. 37 Junction of Nummulitic limestone and Tertiary Sandstone N. end of Kurshru section.

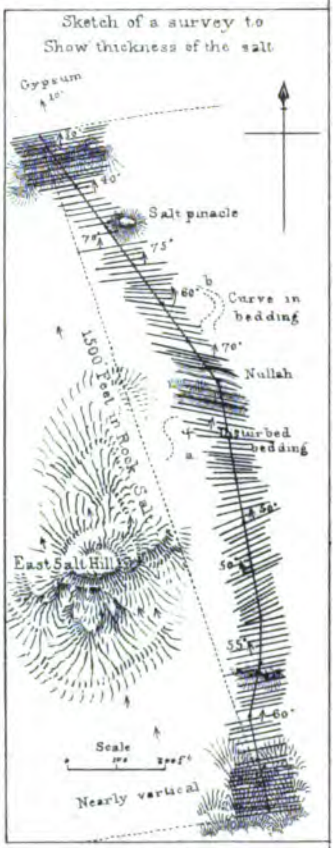


Fig. 39.

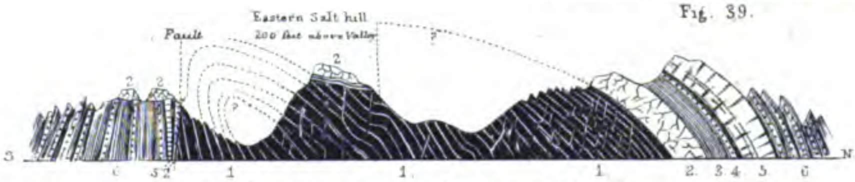


Fig. 38 Section through Bahadurkhel Salt locality

A little further on the salt clay and gypsum with the same arrangement takes even more the appearance of an open curve, but complications soon set in, the stratification of the salt becomes vertical or curved, so as to correspond with the northern side of the anticlinal into which the stream seems to have worked its way.

Faulted southern boundary of salt.

From this place to where the road to Bánnú crosses the salt, some gypsum and less of the nummulitic limestone is seen edging the salt, but close to the road the latter disappears entirely, and soft red clays and tertiary sandstones coming into junction with the salt, the crushing and confusion displayed at the faulted contact is extreme. In the line of the fault small and apparently displaced representatives of the gypsum, the red clay zone with purple sandstones in its upper part, and a little of the nummulitic limestone growing thinner downwards, are inverted, dipping at high angles in a northerly direction.

Gypsum capping tertiary sandstone.

Not far from the road and south from the furthest eastward of the two hills (one of which is seen in the frontispiece) there are some horizontal patches of the gypsum forming caps upon hillocks of red clay and tertiary sandstone, while in the same neighbourhood more of this gypsum rests partly on the same sandstone series and partly on the salt, see Fig 38, which shews the section through the Bahádur Khél salt, east of the quarries. Bearing in mind the Kurshrú Álgud section and its arrangement, it is difficult to account for such appearances as these except under the supposition that before the ground assumed its present denuded form, the solution and removal of salt beneath allowed portions of the gypsum to slide bodily from their places to lower positions.

1. Rock-salt, 1,500 feet exposure. 2. Gypseous series. 3. Red clay zone. (4. Sandstone in 3.) 5. Nummulitic limestone. 6. Tertiary sandstone series. F. Faults.

The salt of this exposure and method of working it will be found fully described in the appendix, so that it will be sufficient to mention its relations here as one of the rocks of the country only.

Fig. 39 is a reduced sketch of a rough survey from one side of the salt exposure to the other with the dips marked, from which it has been calculated that the thickness of the salt at this place is from 1,000 to 1,230 feet, or even more. Its stratification is almost everywhere distinct, and rendered more evident by thin earthy layers alternating with the beds. Here the dip is everywhere northerly—in the lower beds from vertical to 70° declining to 50° or 55°, forming a bold half arch in the central hills, again high after passing these, but gradually becoming lower to 30°, where the last of the salt is seen. There are only two points, marked *a* and *b* on the plan, where some curvature of the beds or disturbance of the steady high dips occurs, likely to reduce the total thickness of the section, and these curvatures appeared to be quite local, not being traceable for any distance, but though the consecutive high dips follow from bed to bed, the strike is not parallel throughout, a result which may be due to pressure or even to concealed fractures or faults, though no such features could be observed in this section, the only marked divisional planes indeed, besides those of bedding, being some strong nearly horizontal joints.

Thickness of salt.

The gypsum capping the central hills presents more difficulty with regard to accepting the measured thickness of the salt as true. That to the north succeeds the salt as elsewhere with apparently perfect conformity. The capping on the hills has the same arrangement as already noticed to the west in the interposition of a greenish-gray clay band between it and the salt, and there is, at all events, a certain amount of parallelism among these beds. Still it is clear that if the salt beds to the north of the hill were produced upwards, they would pass, even at a much lower slope, far above the outlying patches; hence, if the latter are conformable and in their original place, they must either have been embedded in the great salt deposit, or else, being really the lower part of the succeeding zone, the enormous thickness which the salt exhibits must be

Gypsum capping central hills, and their relations to the rest of the section.

a false appearance due to concealed faults or to curves the connexion of which is no longer visible.

But these cappings of gypsum need not necessarily be now in their original places, we have the same rock to the south in utterly abnormal positions, and there is no good reason why these two patches should not also have transgressively subsided from higher levels owing to dissolving of under-lying salt; the situations in which they rested having decided the formation of the hills, to the soluble strata of which they formed a protection against the atmospheric erosion.

Curvature in bedding of salt.

One of the hills considered by itself presents much the appearance of half of an anticlinal curve, and where inversion is so common (the rule rather than the exception) there would be little difficulty in supposing the salt beds to the southward all inverted, if any clue could be found to the fact beyond the reversed dips of some portions of the series just at the line of fault (already mentioned) where local complication lessens their value.

By introducing faulting to the north of the hills, the appearances might also be explained with great probability, but of this no evidence has been detected.

Similarity of salt-rock throughout against faulting.

The similarity of the salt-rock throughout gives it as a mass a unity of character, rendering contortion repeating the same beds more probable than dislocation; a sameness of aspect, too, all but fatal to the hope of discovering repetitions among the layers, more particularly as these are in places strongly obliquely laminated (or false bedded) inducing distrust of discordant appearances.

Possible reduction of thickness incapable of proof.

However the case may be, the fact remains that a cutting 1,500 feet in length could be made as the shortest straight line from side to side through highly inclined rock-salt and nothing else, except the small quantity

of clay associated with it, yet it does seem strange, that while the anticlinal structure pointed out to the west recurs even more strongly about a mile and a half to the east, its disappearance should be accompanied at this the widest exposure of the salt, by an apparently enormous thickness of the deposit, and at the same time the clearest evidence of disturbance at the place, instead of explaining this appearance, should be limited to a large downthrow fault at the outer limit of the salt to the south, which it is not easy to connect in any way with the usual thickness of the salt itself, a thickness which, even if capable of reduction from the above considerations, would still remain large, probably from 350 to 700 feet.

Gypsum.

The gypsum succeeding the salt takes its usual place near Surreenda on the south of the exposure, and thence eastward is often seen the red clay also overlying it, but the nummulitic limestone is much thinner than usual. Northwards of the last named village, and on the opposite side of the salt valley, the gypsum spreads out over bench-like hills lower than the nummulitic limestone escarpment cresting the village and regularly succeeds the salt.

Red clay zone.

Above it the red clay zone comes in its proper place, occupying depression at the foot of the limestone outcrop, having near the base of the latter a well marked band of strong purple calcareous sandstones weathering of a very dark color. These are about 10 or 15 feet thick, (to judge from their broken outcrop); they contain black, flinty pebbles, and on looking over their weathered surfaces some small fragments of bones were found embedded and one small portion of an apparently reptilian tooth. The band is

Fossils.

evidently a larger development of that found on the same horizon in the Kurshrú section and to the west, while the fossils mentioned and the nummulitic layers observed south of Teeree are the only kind of organic remains met with in the whole of the red clay group.

Nummulitic limestone.

In the nummulitic limestone above are some layers largely formed of shell fragments, apparently the remains of oysters,* and higher up numbers of the ordinary *nummulitic* fossils, generally in an imperfect state of preservation. The limestone has much the same thickness as at the Kurshrú Álgud; it curves with an increasing dip to the northwards, and occupies most of the tunnel, by which the road issues from the salt valley into that of Baháđur Khél, near which excavation it becomes nearly vertical.

Tertiary sandstone, &c.

The usual lower beds of the tertiary sandstone series succeed, dipping off the hill, but becoming rapidly perpendicular along the southern side of the Bahádur Khél valley and in the large nullah running along the foot of the salt-quarry hills westward. Very brightly colored red clay and gray sandstones alternate; they are either vertical or dip to the southward as a rule, but half-way between Roghá (Rághú) and Bahádur Khél are closely contorted.

Towards the middle of the Bahádur Khél valley are soft gray sandstones and red clays, with pebbly bands and occasional greenish-gray shaly clays more or less covered by detrital accumulations. The dips are generally high, and also to the south more frequently than in other directions, the beds being probably a good deal folded here and there. The character of the rock indicates a middle or even somewhat higher place in the series.

East part of salt exposure.

In the eastern portion of the Bahádur Khél salt exposure, the salt is seen to form an anticlinal arch with a dip of 50° to the south and 60° to the north, near the Kundo Tapu or boorj. From this towards Rágho it is more concealed by gypsum with black shaly layers and by débris. Its stratification seems to undulate, one dip to the westward having been observed, but to the south

* It was presumably some such beds as these which Dr. Verchere observed, drawing the inference that they were jurassic from their resemblance to other shelly limestones near Kalabagh.

of its area it conforms to the southern side of the anticlinal curve, there strongly indicated by the overlying strata. But on the northern side of this curve, nearly midway between Rágho and Bahádur Khél, the different groups are much disturbed where two small and rather isolated hills stand out from the adjacent ridge.

Contorted and slipped sections to the north.

The most easterly of these shows several slips, repeating the outcropping beds of the red clay and nummulitic limestone groups, and these are faulted against the adjoining tertiary sandstones, a few beds of which occupy a small contorted trough towards the western hill.

Limestone.

The limestone here apparently retains its thickness of 50 or 60 feet, but the hard upper *alveolina beds* were not observed, those forming the local upper part of the group alternating with shaly bands and being highly fossiliferous. At the base of the limestones here are some thin, white, chalk-like layers, one of which is very conspicuous. These white, marly, chalky-bands continue downwards into the variegated clay below, in which three or four of them occur; this clay has the same pale purple tint as in the Kurshrú section, but here it contains many small nodules of brown hæmatite and little concretions stained of a brilliant greenish-blue as if by copper. Below this clay the coarse liver-coloured sandstones of the red clay zone are much exposed, alternating with red clay layers and forming a band of 20 or 30 feet in thickness. They are here conglomeratic, and again were found to contain bone fragments. The rest of the red clay group below is much overrun by débris, but seems as thick as usual.

Purple clay.

Copper-stained concretions.

Anticlinal faulted.

To the eastward of these hills the axis of the Bahádur Khél anticlinal comes out obliquely on the plain or valley to the north, and is cut off by the continuation of the fault at their northern side. Gypsum and gypseous débris with occasional salt exposures and many crater-like hollows indicating its existence

below occupy the whole of the interior of the curve, and bend round the northern slopes of the hills to adjoin the Nurree (Nurrí) outcrop beyond Rágho. The remains of the southern side of the anticlinal rise boldly, forming a fine portion of the arch from Chárpurrá to Shoh (Shágh) and on eastwards to Nurree. In the gypseous series below Shoh one mass of gypsum rested at an angle of 30° unconformably upon reddish gypseous clay rendered flaggy by gypsum layers, showing its stratification inclined at 60° in the same direction as the overlying patch. This is supposed to be another instance of subsidence, *en masse*, of portion of the gypsum owing to removal of its support. In the same vicinity the series seems to have a larger thickness than usual, for regular interstratifications of gypsum and greenish clay in 10 to 50 feet bands undulate to the southward at 45° with a thickness of nearly 300 feet above the salt.

Southern side of anticlinal.

Gypsum series.

The 'red zone' follows in its place, showing a transition from the gypsum by alternating ripple-marked layers of the latter with red clay, but the nummulitic limestone has greatly thinned away, there being in some places but 15 or 20 feet of yellowish, calcareous, marly beds to represent it. A few feet above these, there is a peculiar band among the tertiary sandstones, almost entirely made up of balls of limestone enclosing sometimes black chert nodules. This band makes itself very evident from the way in which its concretions strew the ground, and may be looked upon as, perhaps, the last trace of the calcareous rock producing conditions of the group preceding. Concomitant with thinning out of the limestone, there are near the highest point of the ridge evidences of unequal accumulation of the materials forming the succeeding group; a thick layer of purple clay which rests on the limestone being seen to thin out to nothing, so that an overlying band of sandstone takes its place. Twenty feet above there is a band of

Transition by ripple-marked gypsum layers into red zone.

Concretionary bed above limestone.

Thinning out of limestone.

conglomerate in these sandstone beds, containing numerous pebbles of limestone with *alveolina* and *nummulites* enclosed, both in the pebbles and in the base. Flinty, cherty, and sandstone pebbles of the same kind as the beds above and below this conglomerate also occur with the limestone ones, so that this may be one of the shore deposits of the early part of the tertiary sandstone series, the derived contents of which certainly afford no more evidence of unconformity between the limestones and sandstones than of unconformity within the latter group itself, but may rather indicate formation in shallow water, within reach of wave action, or of distribution of materials by along-shore currents.

Limestone pebbles in lower tertiary sandstones.

The same general succession and southerly inclination of the series of groups extends from hence towards Chárpurrá, north of which place a section of the ground would show again the anticlinal position of the rocks with the salt in the centre conforming to the curve, and the overlying groups dipping north and south at angles up to 50° and 60°.

North of Charpurra.

The great central synclinal of the lower tertiary sandstone series between the Bahádur Khél and the southern ridges of the range, where it is broadest, forms wide open curves with steeply sloping margins, the convergent inclinations becoming less towards the centre of the trough, in which situations the beds are nearly horizontal, the latter position having evidently added to their power of resistance to atmospheric erosion; thus the high plateau of Esár, almost surrounded by precipices, has remained, and the higher mountain to the westward reaching an altitude of 2,838 (+70=2,908) feet. Where the synclinal becomes constricted to the eastward, the beds are longitudinally faulted, and where the sides approach to the westward, compressed and complicated folding of the rocks takes place. (See section Fig. 41).

Central tertiary sandstone synclinal.

Faults.

The rocks which form the synclinal curve are well seen along the Bannú road from Bahádur Khél. Purple and red beds with much red clays are found 100 yards south of where the road leaves the salt at the salt quarries, and the usual gray and purple alternations are crossed to where the road descends an incline beneath the fine cliff called 'Yágœshú cumber' west-by-south from Esár. This is formed of thick gray sandstone with a few dark-gray shale bands below, overlying 150 feet of red clays, the contrast between the textures of these two thick groups having doubtless favoured the formation of the cliff. Among the sandstones at the lower part of the section here some conglomerate layers as before noticed were again observed. From beneath this cliff the road again ascends to the pass of Soordag (Súrdág) through a narrow strike valley where bright red clays predominating among the sandstones give the name to the locality.

Rocks on the Bannú road in the synclinal.

The lower beds of the latter are seen sloping steeply downwards from the limestone surface which sheets the upper part of the Rindghur mountain south of the road and leaving one or two thick projecting patches on its side.

(Súrdag) Soordag Pass.

Towards the southern entrance of the pass where the road turns sharply in that direction to leave it, this Rindghur mountain sinks abruptly, while a lofty wall of the tertiary sandstone and clay series, chiefly gray sandstones above and red clay below, rises for many hundred feet immediately to the north of the road, strange to say, capped at its summit by a small patch of the nummulitic limestone. This place is evidently a focus of complicated crushing and faulting, in the midst of which, close to the base of the northern cliff, and, as it were, passing partly beneath it, is a narrow band of the rock-salt which was traced in a westerly direction for 600 yards, with small masses of gypsum and a portion of the red clay zone along its southern side.

Faults.

Limestone capping tertiary sandstones.

Rock-salt.

Newer tertiary beds.

The whole series of the Rindghur mountain is here, as it were, cut out, and directly in its strike are low hills formed of reddish drab clay with pale whitish-green sandy layers, and broken bands of very soft coarse sandstone, in which may be recognised a portion of some of the highest beds of the tertiary sandstone series. So that here, whatever may be the united thickness of the whole five groups of the country, we have a fault bringing some uncertain portion of the highest against the very lowest rocks of the whole succession.

Section.

Among these low hills, resting upon the soft upper rocks in some spots, or confusedly occurring among them, are very considerable fragmentary patches of the lower shaly portion of the nummulitic limestone. Fig. 40, shews the section at entrance to Soordag pass (Súrdág pass) (about one mile)—

1. Rock-salt. 2. Gypsum. 3. Red clay zone. 4. Nummulitic limestone. 5. Lower tertiary sandstone. 6. Upper ditto. 7. Detrital accumulation. F. Faults.

Details: the salt.

The salt here is of the same character as that at Bahádur Khél, and shows itself in exposures of from 5 to 30 feet high, rising over small spurs which separate the local drainage and holding its way in a tolerably straight line for the interior of the Luttummer anticlinal. The salt is not everywhere visible, being covered by a coating of gray saline clay, on digging into which it may be exposed; this clay seems to have resulted from the decomposition of the salt itself, and is only found along the narrow line which it occupies. The width of the salt varies from a few feet to two or three yards; in some places it appears nearly horizontally stratified, in others to dip northwards at high angles. Towards the west it is covered with disconnected patches of gypsum, having a like high dip to the north.

Red zone.

Some remains of the red clay zone are associated with it, and in these layers of the purple sandstone peculiar to that group also appear.

Gypsum occurs in two bands, one close to the salt, the other parallel to, but separated from, the former, by the red clay band just mentioned.

Curves in cliff.

In the face of the cliff above, two portions of curves in the strata appeared to be marked by the alternations of color of the gray sandstones and red clays as shown in the section. The lower red portion seemed to repeat much of the appearance of the band at the 'Yagœshu cumber', but it would be impossible to say that some of the clays of the red clay zone were not also present.

Limestone cap.

On reaching the small cap of limestone at the upper edge of the cliff it was found to be composed of a few beds of *alveolina* limestone, weathered and shaken, and having no relation to the sandstones on which it rests, the limestone being nearly horizontally disposed, but the sandstones beneath dipping northwards at a considerable angle; the remains of a similar patch were seen at a little distance to the east 25° north. Here also, as if passing below the *alveolina* beds, were a few layers of nearly horizontal, dark, earthy limestone containing rolled *nummulites* and lumps of *alveolina* limestone such as might have formed the uppermost part of the limestone series.

Luttummer anticlinal and faulting.

Almost from the same spot the northern side of the Luttummer nummulitic anticlinal commences, inclined at a high angle to the north, so that it would appear as if this small outlier had once formed a vertical continuation of that limestone band, and when deprived of support had fallen over to the north. Either this or some complicated combination of slipping and faulting must be supposed to account for such an extraordinary occurrence.

Rocks of this anticlinal.

The Luttummer anticlinal is a feature of exactly the same type at that of Suppurrí to the north (already described as the commèncement of this division), but is completely overthrown, both sides of the compressed curve dipping to the

northward at high angles, the apex sinking westward as in the former case, and the southern side apparently sharply reflected upon itself, so as to bring the red-clays of the red-zone into view beneath the limestone both within and outside its southern limb. The gypsum band in the centre is very narrow, the red clays more largely exposed, the nummulitic limestone thinner than usual, containing the usual fossils, and the tertiary sandstone series with a conspicuous red clay band below sweeps round from the northern side, over-rolling and continuing the expression of the anticlinal in finely marked curves to the westward.

The southern flanks of the hill inexplicably confused.

The ground immediately south of this anticlinal between it and the Bánnú road baffles all effort to realise its complicated structure. Large, continuous, contorted, or undulating masses of yellow, shaly, or marly nummulitic limestone containing thick *nummulites* and other fossils project, or overlie apparently the newer sandy clay series. This limestone may have a thickness of over 100 feet, and is succeeded apparently by some of the lower tertiary purple and greenish sandstones and red clays, near which another crag of limestone without any visible relation appears. In another place the newer tertiary soft beds seem to form a dome-shaped mass surrounded by an imperfect ring of the shaly nummulitic limestone, the débris of which dresses all the hills in the neighbourhood, giving the ground a dirty orange colour and smooth barren look.

Upper tertiary.

The soft, coarse, gray sandstones and brown clays of the upper tertiary series are much disturbed, very fragile, and sometimes contain thin veins of heavy spar and occasionally also conglomeratic layers, the pebbles in which are formed of granitoid or other crystalline rocks, with an odd one here and there of *alveolina* limestone, showing that the strange conditions which enabled these latter to be transferred from the place of their formation without any appearance of unconformity between the two groups extended throughout nearly the whole of the newer series. Fig. 41 is a

diagrammatic sectional view of the arrangement of the groups from side to side of the range crossing both the anticlinal and synclinal curves near the ends of the former.—

Section.

2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone 6. Upper beds of same. 7. Detrital accumulations. F. Faults.

Stony belt at foot of hills.

Along the southern base of the hills here from about Luttummer by Soordag and on beyond Goorooza there is a stony belt little inferior in its barrenness to that which is so marked at the foot of the salt range. Its pebbles are formed of the local rocks, and the material, when sections can be seen, is well stratified sandy and stony clay inclined to the southward at angles under 30°. Beyond this zone to the southward all the country is a sandy flat traversed by the broad and shallow beds of dry nullahs, sometimes over a mile in width.

South side of Rindghur mountain.

The southern side of the Rindghur mountain overlooking this low ground eastward from Soordag (Súrdág) also repeats in a great measure the features of the southern escarpment of the salt range; its crest is formed of the hard nummulitic limestone, beneath which some gray clays and the red zone are partially seen, the latter still containing its dark purple sandstone band at top. This soft zone occurring along the outcrop (as in the salt range) has favoured the slipping downwards of great masses of the limestone and other beds below it; false outcrops of these rocks being found on the flanks of the hill resting upon the same drab and reddish clays and coarse sandstones of the upper tertiary bed as occur to the north of Soordag. Except where these subsided masses project there is little to be seen on account of the thick coating of débris with which the slopes are dressed. To the eastward (over a place where a village or hamlet called Sumkilla seems to have once existed) the gypsum appears from beneath the red zone with a thickness of 50 to 80 feet, much entangled with gray and reddish

Salt range character.

clay, the underlying salt being seen in the beds of small nullahs which cut through thick displaced masses of the gypseous series. The latter was here again observed to pass by numerous platy alternations into the purplish red clay above, these harder bands being ripple-marked, and at the place of transition partaking of the color of the upper rock. Some green clays (*Sheen-koura*) are seen below masses of the gypsum, and the whole hill side presents such a confused and disordered appearance, that there is little certainty about the relations of anything below the beds forming the scarp and crest of the hill.

Gypsum: passage into red clay.

Green clays.

In the continuation of the Kurshrú stream at the east end of this Rindghur mountain (here called the Záwá Álgud), a more satisfactory section of the rocks is exposed, from the rock-salt upwards, the latter occupying a width of 500 yards, or 560 paces, measured in the bed of the stream (see Fig. 42).

Goorooza section.

1. Rock-salt. 2 Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone. 6. Upper ditto. 7. Valley beds; detrital, hard, sandy, and conglomeratic. F. Fault.
Dip north, under 45°.

6.—	Salt, gray sandstone, and reddish clays.—Upper tertiary sandstones faulted.		
5.—	Tertiary sandstones, gray sandstones, with a strong band of purple clay; below lowest bed a layer of purple clay	Several hundred feet.	
4.—	Solid nummulitic limestone—*Alveolina* horizon.	95	"
	Nummulitic limestone alternating with shales, most shaly below	90 to 100	"
	Black shales, with a thin irregular layer of whitish, waxy, soapy clay near top	6	"
	Thin, lumpy, calcareous layers	3	"
3.—	Violet variegated clay, hard, light coloured and soft red and gray	10	"
	Red clay, sandy at top, with two sandstone bands, lowest 4 feet, upper 9 feet ...	400	"
2.—	Gypsum, compact, whitish, and gray	30	"
	Green clay	150	"
1.—	Rock-salt *measured horizontally*, bedding not clear, exposed for	1,400	"

This large exposure of salt is almost due south of the quarries at Bahádur Khél, where the horizontal width was little larger; here the bedding lines could not be distinguished with the same facility as there, probably by reason of the lower situation having favoured the accumulation of débris and increased the effect of meteoric water passing over the surfaces. If a general dip of even 35° be allowed for the salt here, however, which would seem lower

Rock-salt.

than the average angle, it would give a thickness of 700 feet for the deposit.

Gray clays.

In the gypsum series the gray clays again appear in the same place as at Bahádur Khél, but the overlying gypsum itself seems unusually thin.

Red zone.

The red clay zone, on the other hand, is very thick. Narrow veins of gypsum traverse the clay, and some of the joint surfaces have a dark shining filmy coating as though of iron or manganese. There are some greenish bands in it towards the base, and its stratification is shown by slight differences of colour or texture. The sandstone bands near the top are also again present. This clay is, as usual, closely united with the pale purple or violet band at top, which appears to form the base of the nummulitic zone almost as much as the uppermost member of this.

Nummulitic group.

The dark gray clay or shale succeeding the first few beds of the limestone has a general blackish look, its position reminding one of the nummulitic alum shales of Chichalí pass to the south, or the dark, pyritous and coaly layers in the Búkkh ravine (near Namal) in the western Salt range. The *alveolina* layers do not begin to appear in this section till half-way up in the nummulitic group, the *nummulites* are most developed also about the middle; and the lowest fossils are small *turritella*-like gastropods and fragmentary oyster shells.

Tertiary sandstone series.

The lowest bed of the succeeding tertiary sandstone series is a purple clay band: some sandstone beds of purplish and gray color succeed, then the thick red clay zone seen beneath the 'Yágœshú cliff,' capped by the strongly bedded soft gray sandstones of Esár, but these could only be seen, not reached, from the gorge, the way being, as usual, barred by a cliff with a deep waterpool at its foot where the limestone crosses.

The whole of this Goorooza (Gúrúza) and Soordag (Súrdág) country suffers much from want of water, that of the Bahádur Khél and Kurruck streams being salt, while the inhabitants prefer carrying it from near Luttummer upon donkeys, to constructing tanks or repairing these when broken.

Want of water.

The only spring that was heard of in the whole country was a very small escape of by no means good water at the limestone outcrop high above the right bank of the Záwá Álgud.

Just at the southern limits of the salt there was observed a small exposure of the upper tertiary soft gray sandstones and clays faulted against the former, and soon covered over by thick, well stratified, hard, sandy, conglomeratic and earthy beds of the detrital accumulation flanking the hills, and having a very decided dip to the south with a predominant reddish color.

Upper tertiary beds and valley deposits.

At Goorooza (Gúrúza) near the chowkí or boorj, a small weathered patch of the limestone rests upon these beds at a considerable distance from the hills, in the same way as some of the craggy patches from this to Luttummer, and although more than half a mile from any projecting exposure of the same rock, this has to be supposed to have reached its present position by means of former landslips when the configuration of the ground may have been very different.

Limestone patch at Goorooza (Gúrúza.)

Close by Goorooza (Gúrúza) to the eastward, the soft gray sandstone or sands, and pale red clays with coarse, rusty, loose, gravelly bands of the upper tertiary are again seen dipping northwards close to the salt, and there are sections showing apparently broken and fragmentary bands of marly nummulitic limestone wedged and crushed among the sandstones, fragments perhaps of the corresponding side of an anticlinal curve which once continued in an arch from beneath the central synclinal over the gypsum of the adjacent

Limestone bands in tertiary sandstone.

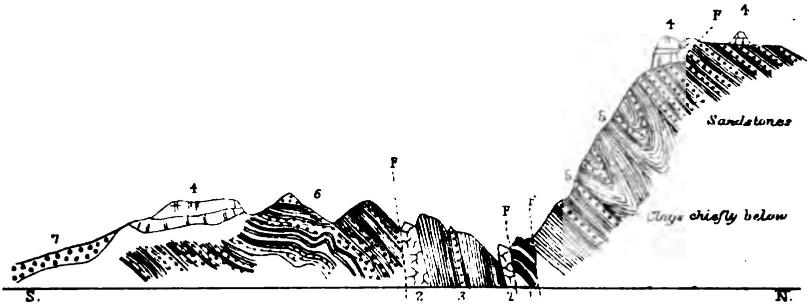


Fig. 40 Section at entrance to Soordag Pass, about a mile

Fig. 41. Section between Bahadurkhel & Luttummer

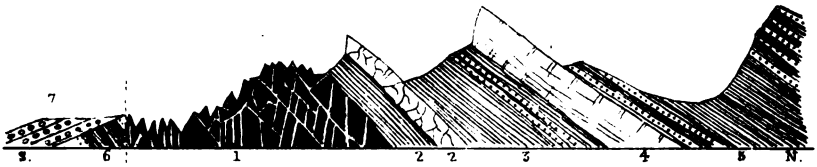


Fig. 42. Section near Goorooza

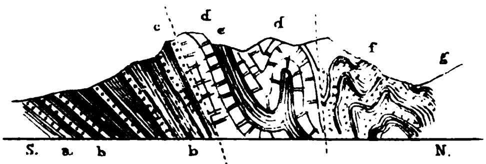


Fig. 43. Section of Nummulitic band E. of Goorooza

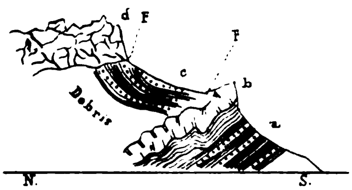


Fig. 44. Western aspect

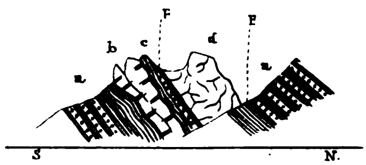


Fig. 45. Eastern aspect

Nummulitic bands E. of Goorooza

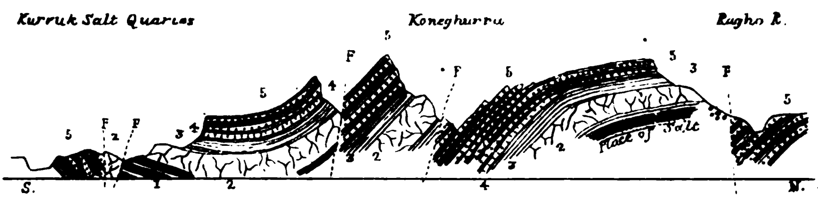


Fig. 46. Section from near Kurruk to near Bagho

outcrop. One little section of a few yards showed the succession as given in Fig. 43.

a. Gray and red soft sandstone and clays, upper tertiary? *b.* Purple sandy clay. *c.* Gray sandstone. *d.* Marly nummulitic limestone. *e.* Purplish gray clay. *f.* Red and gray tertiary sandstones, not so like the upper beds as those seen to the west. *g.* Debris.

Limestone over sandstones.

At another place close by a band of the limestone seemed to have been pushed horizontally over the soft sandstones which dip to the north at low angles, and in several places a mass of these tertiary sandstones was seen in close contact with the outcrop of the gypsum and salt, but capped by small patches of either limestone, gypsum, or the greenish gypseous clays.

Great Báruk fault.

From these facts and the general appearance of the junction elsewhere, reason has been found to conclude that the whole of the Bahádur Khél and Húkaní range from Luttummer to the Shukkurdurra (Shakkardaṛrá) country is bordered by a continuous line of fault along the southern side of the hills, the down throw of which to the south differs in different places, but the general effect to the westward has been to place very high beds of the tertiary sandstones in junction with the salt and gypsum. This great dislocation extends for over forty miles, and in a district where so many disturbances of the kind exist, it has for sake of distinction been called the 'Báruk fault.'

Rocks in nullahs east of Goorooza (Gúrúza).

Two narrow nullahs from the eastward unite at Goorooza (Gúrúza) between which a rounded, elongated hill with a thick covering of gypsum over gray clays rises high enough to be visible from long distances, coming out from beneath this gypsum at its faulted outcrop along the right bank of the southern nullah; the rock-salt also crops with an apparently varying thickness of 15 to 20, and sometimes even much more than 50 feet; where not visible, its white 'shor' efflorescence is frequently seen, enabling it to be traced for more than half the length of the little valley, obscurely associated with the fallen masses of gray '*Sheenkoura*' which intervene

between it and the gypsum. The opposite side of the glen exposes red and gray disturbed tertiary sandstone and clay beds, or the unconformable surface deposits sloping to the south.

Among these tertiary sandstones, &c., are beds having much more the aspect of the lower than the upper part of the series seen to the west. They are all disturbed, dipping northwards at 40°, 15° and 20°, and sometimes show synclinal curvature pushed over to the south. Intercalated in a purple portion of these beds, shaly below and with sandstones above it, is a thin, yellow, marly nummulitic layer, the association of the rocks much resembling the thin limestone bands of the Subathu rocks along the northern side of the Potwár country. At another spot a little to the eastward similar thin bands of limestone were again noticed in these purple and red tertiary rocks. One side of an exposure near a saline spring showing an appearance so different from the same viewed a few paces to the eastward looking back towards the first that these (Fig. 44. and Fig. 45) may be worth representing to show the complicated structure of the ground along the line of fault. Fig. 44 shews the western, and Fig. 45 the eastern appearance—

Complicated sections.

a. Purple and red tertiary sandstones, &c. *b.* Nummulitic limestone with *Alveolina* and *Nummulites.* *c.* Tertiary sandstone, &c., again. *d.* Gypsum, fault between *b* and *d.*, and slips also probably adjacent.

The limestone in both cases *appeared* to be truly intercalated in the purple and red tertiary sandstones, but it could not be ascertained whether both were parts of the same band slightly displaced by slippage, or whether the eastern, which lies a little to the northward of the other, was a different and somewhat thicker layer. Neither exceeds 2 or 3 feet.

It is difficult to say what combinations of slipping and faulting may have occurred here, but further east towards the head of the nullah, where the tertiary sandstones are much contorted, the anticlinal axes sloping to the eastward, displaced patches of the red clay zone occur, and in one bank, lumpy, marly limestone such as that abovementioned, was seen in an inverted

Relations better seen to east, but inverted.

section overlying purple clay and sandstone, and succeeded by some of the deep red clays of this older zone, showing that inversion, as so frequently the case, has added to the local complexities, and very probably aided the disturbed and broken rocks in settling into anomalous positions.

Upper tertiary beds disappear.

Although the junction beds have here no longer the upper character previously described, that these upper beds occurred at no great distance may be inferred from the large proportion of crystalline and granitoid pebbles occurring among those of the local rocks in the bed of the Álgud.

The northern nullah east of Goorooza.

The northern nullah traverses the thick red clay zone beneath the outcrop of the nummulitic limestone (here rapidly growing thin) and that of the overlying lower sandstones, these forming the openly undulating south side of the great central synclinal trough. The diminished thickness of the limestone here may be noticed in connexion with the small show it makes among the complicated exposures just now mentioned.

Summit of gypsum ridge.

The summit of the gypsum ridge forms a commanding point of observation. To the northwards the tertiary sandstones, &c., roll over elevated ground sweeping downward into the synclinal valley, on the other side of which they are seen to rise again, the widely extended and gently curved surfaces of the naked rocks forming a fine study of contortions. To the eastward these beds curve over the edge of the synclinal and decline gently southwards to the broken and sinuous outcrop of the whole series of groups towards the fault, where the nummulitic limestone only shows itself in the escarpment as a thin and fugitive band, sometimes entirely absent. The red zone and gypsum appear below, but in much less force than near and on the ridge from which the observer is supposed to look, and the dark rock-salt, though not visible from a distance, occurs beneath all, its presence being certified by the inevitable guard tower or boorj

in the direction of the village of Tuppee (Tupí). To the south of the outcrop is the sandy bed of the upper Koshee Algud bounding a large cultivated tract in the Báruk valley (an oasis in this barren country), between the Bahádur Khél hills and the rugged lofty Sheenghur mountains to the south.

Salt of Tuppee drung.

The salt at the Tuppee (Tupí) drung locality dips to the north at 30° and 40°, and shows the horizontal joints noticed at Bahádur Khél. Lying low, its quarrying is much interfered with by springs of brine. At this locality again a broken band 20 feet wide of nummulitic limestone occurs in the tertiary sandstones dipping towards and close up to the salt, the faulted junction here bending to the northwards beyond the general face of the high gypsum-covered hill to the west. In these sandstones, too, dipping northwards at 55° close to the fault, a soft coarse gray layer was observed enclosing scattered *nummulites* which may have been rolled, though the usual rounded lumps of limestone which occur so frequently near similar evidences of derived nummulitic materials did not accompany them. The beds near are also much contorted. Gypseous seams were here again noticed in crossing the clays of the red zone. Here, too, the overlying detrital valley beds seemed not to have escaped disturbance, a synclinal fold being seen in them close to the gypsum and gypseous clay. Under ground wasting of some of this soft series, however, may have produced the result.

Sandstones containing scattered nummulites.

Valley bed.

Kurruk salt locality.

At Kurruk the salt is two or three hundred yards wide and less than a mile long, but has very indefinite limits of exposure. It dips steeply to the northward, and possesses much of the appearance of that at Bahádur Khél in some beds, though clearer looking on the whole and said to be heavier.

Faulted complications.

In this neighbourhood other fault complications affect the rocks, one slip making a portion of the gypsum apparently dip beneath the salt. Another strike fault coin-

cides with a nearly east and west ravine among the tertiary sandstones to the northward, exposing a portion of the underlying series, and yet another, parallel and passing northwards of a part of this, is shown to occur by a strong rib of gypsum appearing again among the tertiary sandstones. These faults and the low cliff-like outcrops of the sandstone series about here give many opportunities of observing the disappearance of the whole of the nummulitic group, a thin representative of which is occasionally seen, and even this sometimes is entirely absent. Fig. 46 is a section across range from near Kurruk to near Rágho—

1. Rock-salt. 2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone and clay series. F. Faults.

Sections described.

In Fig. 46 the Koneghurra fault, which is dying out just where the section crosses, is represented to show the character of this part of the range. The gypsum is much broken and often partially concealed, but its relations to the other rocks were made out as above. There are associated with it bands of green clay sometimes above or near the top, but generally below.

Red zone.

The red zone still continues, but less thick than to the west, and there are appearances of it on both sides of the gypsum in Koneghurra glen.

Limestone.

The nummulitic limestone has dwindled away to a few lumpy beds closely associated with the violet clay at the top of the red zone, and its junction with the overlying sandstones again shows the peculiar transition between these groups.

Junction of limestone and tertiary sandstones.

The lumpy limestone has its blocks separated by a sandy matrix, for a foot or two above which the sand increases, and the rock is sandstone, containing shapeless lumps of limestone, none of the corners of which are sharper than those in the limestone bed below. The lumps of limestone grow gradually smaller and fewer upwards, but after some few feet recur again in greater

quantity. Even where the limestone band has entirely disappeared, the sandy beds with limestone lumps resembling conglomerate are seen, sometimes containing *nummulites* in the matrix, and showing that these have not been derived from very local erosion of the limestone, nor does the junction of these beds with the underlying violet clays of the red zone show any sign of previous erosion or disturbance of the latter, the impression conveyed being that the limestone has tranquilly died out, sometimes leaving a couple of thin marly streaks to mark its position, and that the next succeeding beds as tranquilly took its place, the limestone lumps in these being in some cases mere nodules, indicating that the calcareous conditions had not altogether ceased, in others, perhaps slightly removed, and slightly rolled fragments conveyed by currents possibly even before the rock had acquired any high degree of hardness.

Bone beds: fossil timber.

On the Andai plateau and the slopes above, the lower sandstones are thin, and here contain numerous fragments of exogenous fossil-wood as well as fragmentary bones and lumps of the nummulitic limestone, all of which occurring near each other are especially characteristic of the lower beds.

Lukhí salt exposures.

Eastward of Kurruk in the neighbourhood of Lukhi small exposures of salt again occur near the banks of the stream from Turkhakooa, and not far from the fault, the existence of which is shown by the tertiary sandstone, red and gray beds dipping northerly at 45° towards the gypseous, red and tertiary-series on the northern side of the stream. Here at the termination of a patch or lobe of the sandstone series the rocks are greatly broken up and cut through by faults, between two of which a wedge of these beds is deeply let into the gypsum. Green clays are associated with the latter, and patches of the red clay zone are rather confusedly distributed.

Faults.

Turkhakooa to Nurree.

From Turkhakooa (Turkakúa) to Nurree (Nurrí) the whole range becomes reduced to a width of about two miles, and though of no great height, the hills are so

difficult as to be barely practicable for any except foot-passengers. Fig. 47 shews the section from Nurree (Nurrí) to Turkhakooa (Turkakúa) across the range, two and a half miles—

1. Rock-salt. 2. Gypseous series. 3. Red clay zone. (4 Wanting.) 5. Tertiary sandstone series. F. Faults.

Section.

In the section the double anticlinal character of the range is again apparent in the two parallel elongated exposures of the gypsum on either side of the continuation of the tertiary sandstones which form the great synclinal to the west, this synclinal being here apparently inverted. Faults occur both at the north and south limits of the range, that to the north being a continuation of one previously mentioned as cutting off obliquely the extension of the Bahádur Khél anticlinal, and that to the south the great Báruk fault.

Faults.

Nummulitic limestone absent.

The Bahádur Khél anticlinal, however, does not seem to have been entirely cut off, as the curve of its southern side is continuous from Shoh to beyond Nurree. In the northern outcrop of this southern curve and also in that surrounding the Turkhakooa and Sirraikhwá gypsum, the nummulitic limestone may be said to be entirely absent for a distance of twenty-four miles, or only represented by a few thin layers of the lower part here and there of no great lateral extent, or sometimes a 3-foot pebbly-looking bed of the lower sandstone, enclosing nummulitic limestone lumps, feebly indicates places where it ought to exist.

Lower beds of limestone represented.

One of these narrow layers of this limestone united by a thin band of blackish shale (such as was noticed at the base of the group in the Záwá Algud), to the violet or lavender-clay below is seen to the southward of the salt chowkí or tower on the hill in which the salt quarries of Nurree (Nurrí) are situated.

Gypsum.

The gypsum of this locality seems much weathered and disturbed by atmospheric action, presenting, as usual, only unsatisfactory evidence as to its thickness and

stratification, but accompanied along its upper side by a fair representative of the red clay zone. To the southward, too, towards Turkhakooa, the gypsum sprawls over the ground with a large surface exposure from which little can be learned. The sandstones intervening between the two exposures are evidently low in the series and contain much red clay.

Rock-salt of Nurree (Nurrí).

The rock-salt shown in the above section is not exposed at Turkhakooa (Turkakúa), but occurs to the eastward within three miles. At Nurree a good deal of it is seen forming the core of the high gypsum hill (south of the village), which is deeply penetrated by great crater-like hollows, the rain water collecting in which must find a subterranean outlet through the salt. The latter is whiter and cleaner than that at Bahádur Khél or Kurruk, and is thought to be some of the best salt in the country. Its stratification is not everywhere evident, but seems to correspond with the half anticlinal in which it occurs, and its thickness is apparently great, there being almost continuous exposures of 200 feet in the sides of the crater-like hollows, for a long distance beneath which the salt may be fairly supposed to extend.

Contortion north of Nurree salt quarries.

From the salt mines hill at Nurree (Nurrí) looking over the valley or plain to the north, in which the watershed between the Teeree river and Bahádur Khél streams lies, one of the finest examples of contortion on a large scale in the whole district may be seen, the tertiary sandstone series forming a wide synclinal curve, extending from the foot of the hill to the Bánnú road' near Totukhí. Within this harder ridges of the sandstone are seen successively coming round by Inzurruppa towards the Speena hills, and turning back by Nurree forming a great horse-shoe bend open to the west. The character of the lower beds in the Nurree (Nurrí) tributary of the Teeree Towey (Tírí Tauí), their dark red and purple colour, is distinct, while higher up in the series westward towards Rágho the prevalence of drab color among the clays can be seen even at this distance. The axis of the curve runs about 25° south of west.

Sirraikhwá: anomalous position of gypsum.

At Sirraikhwá just above the village, another of the many instances of anomalous positions assumed by the rocks of the district occurs, and one not easy to explain, unless the thick mass of gypsum which here extends beyond its usual boundary and rests clearly on the tertiary sandstones be supposed either to have travelled from its place down a once higher slope, or, with greater probability, to be a recomposed mass formed from the solution of the neighbouring gypseous series, after the manner, somewhat, of calcareous tufa. The appearance presented is figured below :—

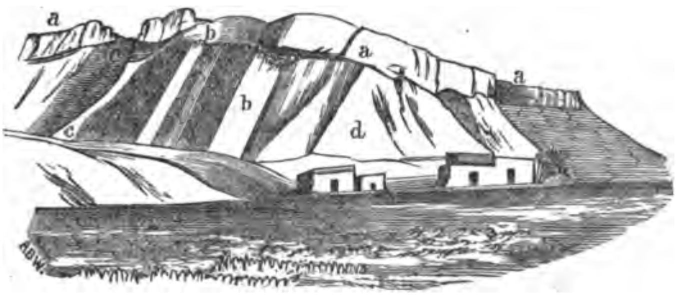


Fig. 48. Gypsum above part of the village of Sirraikhwa (Sirrwaikwhá) looking east.
a. Gypsum. *b.* Tertiary sandstone clay. *c.* Red clay (? the red zone). *d.* Débris. *e.* Green clays under gypsum, close to supposed place of fault.

Báruk fault.

Close to where this occurs is the place of the Báruk fault, and the red clays *c*, may possibly be those of the red zone, which it is hardly possible to identify in some situations where nummulitic limestone is absent.

Salt locality.

The Sirraikhwá reputed old salt quarries are situated not very far from this spot on the higher ground above the village, surrounded by masses of gypsum and gypseous débris. At the western exposure the salt has a surface exposure of about 35 feet in height, thickly covered on top by débris, the beds dipping north at 40° and 50°, and the salt having very much the character of that at Nurree (Nurrí). Nearer the Sirraikhwá *boorj* there are three subsidences, one being a large double pot hole or crater-like hollow, indicating the removal of salt from below. Close by there rises

a conspicuous hill, much of which is made of salt having a low dip to the northward of east, and showing oblique lamination in such a way as to indicate that the deposition took place from the northward. The hill shows a section of nearly 200 feet in the salt, to which must be added the unknown quantity shown by the occurrence of the craters to have suffered subterranean erosion. This hill is capped by gypsum, with a 15-foot band of green clay towards the top. The gypsum passes by thin alternations into the succeeding red clay zone, and resting upon this without a vestige of the nummulitic limestone or the lavender-clay intervening, is a strong escarpment of the lower purplish tertiary sandstones, the stratification of which at the junction appears somewhat irregular, but not sufficiently so to warrant any assumption of unconformity, although the basal beds sometimes contain the usual limestone lumps. These sandstones conform to the narrow anticlinal easterly ending of of the Sirraíkhwá gypsum, their inclinations approaching the vertical near the apex of the curve. Some grayish sandstones forming the upper beds of the escarpment abound in fossil, apparently exogenous, timber, a gnarled, knotted, and once branching trunk which lay prostrate, weathering from the rock, being found to have a length of 20 feet, while slightly separated portions of it were traced for 40 feet further.

Gypsum passing into red zone.

Nummulitic limestone absent.

Tertiary sandstones.

The ground north of Tubbaikhwa formed of sandstones and clays immediately succeeding these, is extremely bare and rocky where traversed by the pass of Kohneega (Kohníga) to Nurree (Nurrí), a large space being occupied by a group of bright red clays which, with the associated sandstones, are intensely contorted and crushed in the region of the Báruk fault.

North of Tubbaikhwa.

These sandstones and clays form a continuation of the series of the great central synclinal of the range to the westward, no longer recognisable here, for the beds over the axis of the narrow Sirraíkhwá anticlinal and along its northern

Continuation of central synclinal.

side are vertical, rising like a wall, with one very conspicuous peak, between this sandstone and clay ground, and the wide gypsum expansion of Speena (Spína) to the north (called Ispeenha on the map).

Speena (Spína) gypsum tract.

This large exposure of the gypsum occurring within much narrower limits on either side is apparently a resultant of complex thrust and resistance to the contorting forces arriving at this place from different directions, one of the most powerful impulses coming apparently from the westward in the direction of the great synclinal curve occupying the low ground at Nurree (Nurrí,) and perhaps influenced by special lines of weakness, which, so to speak, diverted the Nurree (Nurrí) fault to the north of this gypsum tract.

Bounded by vertical strata.

The latter is enclosed on all sides, save where the gypsum continues from it, by vertically bedded rocks with a tendency along the northern side to inversion; within these the gypsum rises covering heavily undulating ground traversed by deep nullahs; its want of variety and contrast to the sharply serrated adjacent sandstone and clay country being evidently produced by the homogeneous nature of the rock, the white colour of which has given the place its Pushtú name, though veins of reddish and yellow colour also occur. Most of the rock is naked, but there is an inclination among the water-courses to silt themselves up, thus forming lakes or small alluvial hollows, and where there is any soil, it is said to be the most productive in the country. A large pond or 'dund' exists in one of these hollows, having no escape unless there be some subterranean exit, and a fabulous reputation for the coldness of its water. In the bed of another, which had evidently found a way to drain itself by a stream course now traversing the spot, small dead *Planorbis* like shells and the fossilized stems of marsh plants converted into yellow carbonate of lime were found embedded in a stratified gray sandy clay. The latter attracted attention by their numbers and the startling resemblance of their cylindrical forms to Belemnites.

The gypsum.

Lakes or "*dunds.*"

Towards the higher parts of the gypsum ground, large, circular, or elongated spaces seem to have fallen in forming deep hollows, in which a great quantity of the underlying rock-salt is exposed, its stratification being either horizontal, or gently undulating, and conforming to the clays and gypsum above. At one place here a 15-foot band of gray and reddish dark-mottled clay intervened between nearly horizontal gypsum and a 50-foot exposure of the rock-salt below. Not far from this the gypsum contains scattered crystals of iron pyrites. Some of the large salt exposures here were estimated to have a depth of more than 200 feet; they lie chiefly at the north-west side of the tract, and send a copious supply of the mineral in solution to the streams below, as shown by the quantity of 'shor' visible in their beds.

Speena (Spína) salt.

The red zone is here chiefly visible from the color of its débris around the outer limits of the gypsum: along with it at the western side of the latter a few beds of gray sandstone, much like those of the tertiary sandstone series, were observed which might have been a local development of its upper sandy layers, but everything about the place was so much disturbed, that these might even have belonged to the higher group here let in by faulting.

Red zone.

On the northern side of this Speena gypsum and red clay zone the nummulitic limestone re-appears as a narrow, vertical band bending also round to the west and southward till suddenly cut off by a fault in the pass of Kohneega (Kohníga). It is much disturbed and slipped in places, one vertically bedded mass having been observed separated by an inclined slippage plane from likewise vertically bedded tertiary sandstones on which it rested. Further west, on crossing it from the Speena (Spína) salt exposures to Nurree, its lower layers were found to be earthy, containing only obscure spiral shells and the main mass of the *alveolina* kind; while the uppermost layer of all was a limestone conglomerate, the pebbles or lumps in which were mostly of limestone as was also the base, the latter containing *alveolina*.

Nummulitic limestone.

Limestone conglomerate.

In the pass of Kohneega (Kohníga) at its narrow northern opening the confusion of the rocks is extreme. The salt is seen above its eastern side amid a crushed mass of the clays of red zone, on which detached fragmentary masses of gypsum rest. The latter on the west side of the pass has a thickness of 100 feet, dipping steadily to the east of south at 60°, succeeded by the tertiary lower sandstones with a higher dip of 70°, in the same direction and some traces of the red zone between. The limestone comes from the north-eastward perfectly vertical, but just where it ends is doubled partly back upon itself, increasing its apparent thickness to nearly 100 feet, and in its general strike on the west side of the pass a small mass of the limestone is crushed in among vertical tertiary sandstones faulted against the Nurree (Nurrí) gypsum. The vertical and highly tilted bedding of the latter soon gives place to more moderate dips as the beds pass gently beneath the Nurree (Nurrí) synclinal.

Salt at pass of Kohneega: crushing and faulting.

Northward of the Speena (Spína) gypsum tract the whole valley, across to the Bándá hills, is occupied by a perfect quaquaversal basin in the tertiary sandstones little less in size and more complete than the Nurree (Nurrí) feature. In the very centre of this a tabular mass of the sandstones edged by mural precipices rises considerably above the neighbouring country forming the picturesque site of the ruins of Sháh Báz Ghur. Within this basin the gray sandstones and red clays have the appearance of the middle rocks of the series, and in the stream course beneath the hill on which the ruins stand numbers of crystalline erratics from the upper conglomeratic beds of the series were found, whence it may be inferred that these also once overspread this part of the country.

Tertiary sandstone basin of Sháh Báz Ghur.

An isolated and elevated trough of the lower tertiary sandstones, nearly of the same size as the Speena (Spína) gypsum tract, occurs to the eastward, forming the upper portion of the mountain, summits of which are called Muzdukkai Sír and Kurar Sír.

Tertiary sandstone synclinal of Kurar.

The eastern side of this trough is a simple synclinal, but to the west at the narrowest part of the whole range the curve is overthrown to the south. The section, Fig. 49, is taken nearly midway between and shews a length of about two and a half miles.

1. Rock-salt. 2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone. 5a. Beds towards upper part of same series. F. Báruk fault.

The nummulitic limestone is absent or but slightly represented to the west of this synclinal, but to the east is largely displayed from its position more than from its thickness. The red clay zone is seen beneath where not interrupted by faulting, the gypsum occurs below, and the rock-salt is locally largely exposed to the south, in the escarpment of the mountain below the summit of Kurar.

Section in Algud near Lakkona.

An interesting but complicated section is exposed in the Álgud which crosses the range running northward in a deep ravine between the Kurar synclinal and the Speena (Spína) gypsum tract. Descending this ravine from near Shaidan, tertiary, red, and gray sandstones and clays are passed through, dipping southward at 70° or more nearly vertical. Red clays of the red zone with a thickness of 150 feet underlie these, or would, if there was any underlie to speak of. Gypsum, nearly vertical or dipping at a very high angle to the south, 155 feet thick, and with greenish clays on both sides, is then passed. In the lower part of this gypsum the southerly dip lessens to 60°, and the beds are contorted. A few yards further on apparently the same mass of gypsum, curved and undulated, seems to increase enormously in thickness up to 300 or 400 feet, 30 feet of its lowest part being dark or black and bituminous calcareous shales

Dark gypsum and sulphurous springs.

(see analysis No. 2, page 48). At this place sulphurous springs break out at the sides of and in the Álgud, the whole place smelling strongly of sulphuretted hydrogen. For several yards further, disturbed and partly inverted gypsum is seen, and then the red clay zone is entered with a local appearance of large thickness. Its red sandstone bands near the top are also largely

Bituminous sandstone in red zone.

developed, but irregular, and a layer of these from 3 to 4 feet thick is quite black, heavy, damp-looking, and smells so strongly of petroleum that it might be found with one's eyes closed. A few bands of brownish red clay intervene between this and the violet clay band above, immediately over which the nummulitic limestone comes in rather strongly, with an apparent thickness of 50 to 75 feet, vertically bedded, but its cross section, as is often the case, inaccessible for measurement.

Mineral in limestone.

On the basal surface of one of its lower beds groups of stars, at first looking like clusters of coral, were observed. On closer examination these were found to consist of a whitish mineral, in radiating prisms, some of which, on being tried by Dr. Warth, gave the red flame of strontian before the blowpipe.

Beyond the limestone to the north the lower tertiary sandstones were seen to succeed it, and another rib of this limestone brought up by disturbance occurs among these further northward near Krunzeenai (Krunzínaí).

Section in and above right bank of Algud.

Ascending the left bank of the Álgud, gypsum and gypseous débris only were observed, hemmed in on the north by a limestone rib, with traces of the red zone at its base, and on the south by the lower tertiary sandstones and clays, but above the opposite bank the distorted synclinal admitting the last named beds was seen; the section being confused here and there by slippage of different portions of the rocks on the steeply sloping hill side. See Fig. 50, which is a diagramatic sectional representation of the rocks on right bank of Algud near Lakkona and of Muzdukkai hill looking east.

2. Gypseous series. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone, &c.
a. Greenish clay. *b.* Petroleum impregnated sandstone. *c.* Débris.

Down in the ravine it is not clear how the beds are arranged, but from above the Speena gypsum is seen to divide into two bands, each

taking the opposite sides of Muzdukkai hill. From the general arrangement of the beds both of these bands appear to have filled the interiors of anticlinal curves, the positions of which were altered by lateral pressure and their ordinary relations obscured by faults.

Section near Nishpo.

In the bed of a deeply cut ravine from the Kurár mountain escaping from its northern side near Nishpo, at a place called Z'murree (Z'murrí) Thang (or tung), one of the very frequent constrictions of the gorges as they traverse the nummulitic limestone occurs, leaving, indeed, no visible passage except that for the water of the stream through the vertical wall of limestone. A precarious footing may, however, in one place be found overhanging the deep pool below, around which the rocks are all exposed.

Alternation of limestone and lower tertiary sandstone.

Here some beds of the limestone are most strangely placed, the upper layers being apparently intercalated and dovetailed with the lower beds of the sandstone in contact after a manner that cannot be altogether attributed to crushing or pressure, and would seem fatal to the idea of unconformity between the groups. Fig. 51. shews this section at Z'murree (Z'murrí) Thung waterfall.

2. Gypsum. 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone.

The band of limestone marked (*c*) continues up the right bank of the ravine, but seems to have thinned away on the left bank; the intermediate reddish purple clays and sandstones apparently thin out to the east, but contain calcareous layers (*a*) and (*b*), which as well as (*c*) contain *nummulites*, the upper band (*c*) being of a gnarled, lumpy, mixed, sandy, and limestone nature.

Magnesian limestone associated with gypsum.

The mass of the limestone at the waterfall is locally thin and of the hard *alveolina* variety, and the red clay zone and gypsum come in immediately behind it. Over the surface of this gypsum small fragments of magnesian limestone layers evidently associated with it were observed, and the limestone was seen again edging the southern side of the gypsum.

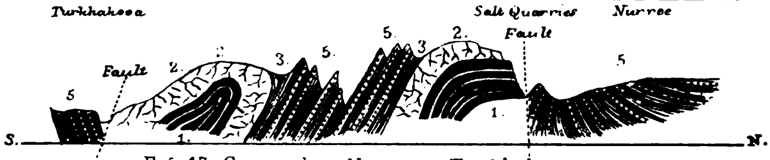


Fig 47. Section from Nurree to Turkhakooa.

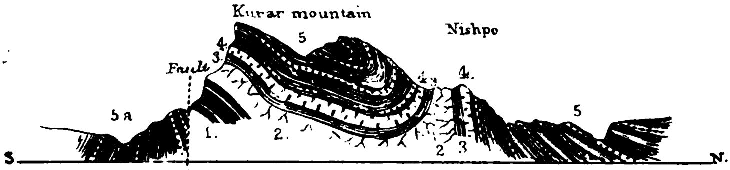


Fig. 49. Section across Kurar mountain

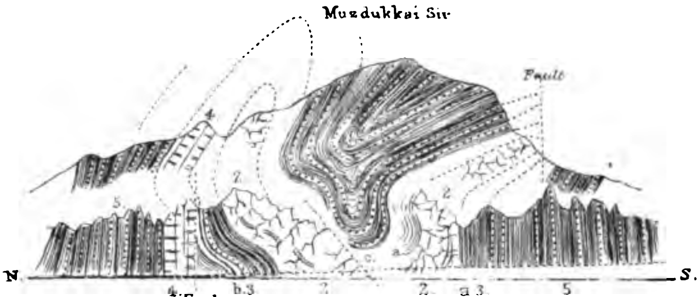


Fig. 50. Diagram of rocks on and above right bank of Lakona Algud.

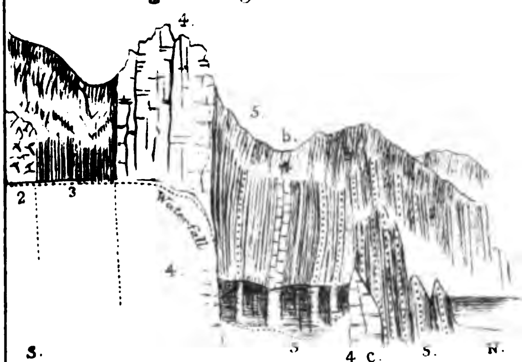


Fig. 51. At Z'murree-thung waterfall

Fig. 52. Oblique lamination S. of Sunda Kullakhel.

Fig. 53 Section down the Mittan Pass.

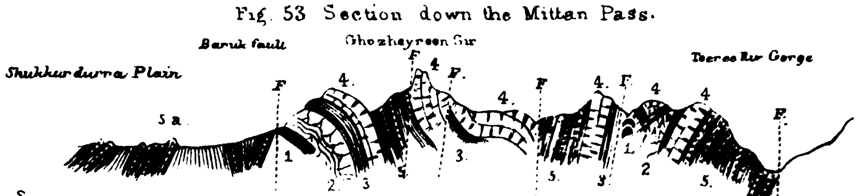


Fig. 54 Section from Zertungi to Shukkurdurra Plain

To the north of this place in the neighbourhood of Sundá Kulla-Khél, the tertiary sandstones undulate in wide curves over the ground, but dip steeply to the south in the banks of the Teeree Towey (Tírí Tauí) river. Red clays are largely associated with the gray sandstones towards the hills south-west of the above-named village, forming a large anticlinal curve in the direction of the axis of the Sháh Báz Ghur basin. Where this curve is crossed by the deep Álgud from the Lákkona ravine, much irregularity of deposition was observed at one place on a sufficient scale to have been mistaken in a smaller exposure for unconformity or overlap. See Fig. 52.

Tertiary sandstones near Sunda Kulla Khél.

The Kurár salt locality on the southern side of the hills is a very large exposure in the lower part of the cliff, in which the faulted and apparently rugged surface of the salt has been so clearly pressed against the sandy clays and incoherent sandstones of the adjacent middle portion of the tertiary beds that portions of these have been left as it were inserted between the salt and gypsum as well as entangled along the outcrop of the salt.

Kurar salt locality.

Above the gypsum the red clay zone and nummulitic limestone are seen in the escarpment, the top of which is formed by lower tertiary sandstones, the nummulitic band at one spot appearing twice, separated by over 150 feet of the former, as if a portion of the escarpment had slipped downwards.

Limestone outcrop.

The salt, of which fully 150 feet is exposed, is here exceptionally pure, having less traces even of intermixture with blue clay than usual, and the upper beds, as at Jatta and several of the eastern localities, contain black bituminous bands.

Salt.

The pale, bluish-gray, micaceous sandstones, with many alternations of bright red clay, have a very soft texture, and appear to belong to the upper rather than the lower portion of the tertiary sandstone series, brought into this place by a

Character of upper tertiary sandstone.

continuation of the Báruk fault. They strike pretty steadily east 20° north, and are either vertical, or dip at high angles from the hill.

Limestone.

To the eastward of the Kurár synclinal, which is here much more simple in its structure, the nummulitic limestone forms a large sheet conforming to the curve, but most exposed at its southern side lying between the two bands of gypsum embracing Kurár mountain. Owing to some irregularity of the axis of the curve, the limestone sinks comparatively low to the north of Dund, a village which takes its name from a small rushy lake without an outlet situated in this low ground. An east and west fault is believed to pass just to the north of this little lake separating the limestone from a long rib of gypsum, between which and this limestone tertiary sandstones, also believed to be faulted, come in to the east.

Dund.

Fault.

Gypsum.

In this direction also, within a couple of miles of Dund, the other (southern) gypsum zone rises as the adjacent river falls, till it becomes a lofty mass closely flanked by the sandstones, &c., to the south, contorted, nearly vertical, or sloping away from it. Upon this gypsum the red clay band rests, and is succeeded by the limestone, while in the southern face of the gypsum itself are one or two small exposures of the rock-salt.

Durree salt locality.

One of these is called Durvee or Durree drung, situated at the bottom of a deep ravine in the gypsum; but little of the salt is seen, and this shows a northerly dip.

The gypsum above is much disturbed, and often covered with its own débris, or that of the red clay zone, sometimes appearing as if enclosed within it, or caught in contortions.

Pisolitic hæmatite.

In the sandstone layer of the latter band there occurs here a purple and green gravelly-looking finely concretionary hæmatitic bed only worth noticing as it may

possibly indicate the source of the Wuzeeree (Wazírí) iron imported from that wild country lying to the westward of this district.

The overlying limestone is contorted and disturbed, rolling over the hills with a preponderance of northerly dip.

Southern ridge dies out, the range continued by two others.

The ridge formed by this gypsum and limestone soon declines and disappears, but the range is carried on eastwards by two others from Kurár mountain, one of which to the north, called Zyaruttí páhár, shortly becomes separated from the intervening ridge by a considerable rugged and rocky central valley. This Zyaruttí ridge, like many others of the country, is a half anticlinal, the other half having disappeared in a long fault at its southern base. At its western end the anticlinal just overturns the axis, the limestone being followed round by fine bold rocky outcrops of the tertiary sandstones. Close to the eastward of the summit the arrangement is somewhat disordered by a cross fault which clearly lets down a mass of the sandstones below the limestone level. From this to the interruption of the ridge at the Mittán pass the relations are normal, the gypsum, red zone, nummulitic limestone and sandstones, &c., succeeding each other, but towards the pass the limestones come more across the axis tending to complete the curve, while the southern or gypseous slope is, as usual, smooth or overshot by débris, and fails to expose the rocks as they project on the crest and northern side.

Zyaruttí ridge.

Salt localities.

In the gypsum area nearly beneath the summit are two small (reputed) rock-salt localities. This Zyaruttí hill commands a fine view of the neighbouring country and the Suféd Koh and other Afghán mountains rising behind the Affreedee (Affrídí) hills. Its section, however, does not seem to present anything remarkable, except that towards the lower half of the nummulitic limestone, there are some of the white softer marly beds abounding with the usual fossils,

Fossiliferous bands in the limestone.

among which the rough *Gryphæa*-like form alluded to as characteristic of this Trans-Indus nummulitic rock is conspicuous.

Mittan pass.

The Mittân Turtullí, or (as the natives call it) Turrilla, pass, is the bed of a deeply cut ravine, the stream of which is formed by the collection of several others from the Lukkur Ghur mountains and the south side of Kurár, the most important ones uniting near Dund. The stream thus formed is one of the numerous examples in the country of its main drainage bearing little relation to the disposition of its ridges, these latter being crossed in various places by every considerable stream in the district. Following the river through the Mittân pass towards the Teeree Towey (Tírí Tauí), the red clays and soft gray sandstones seen from Kurár to the end of the Dund ridge are found to dip at high angles to the south, becoming vertical just at the latter spot. The Dund limestone of the left bank is cut out by a fault, and behind, or immediately northwards, lower, purple and gray tertiary sandstones, &c., are also highly inclined to the south. Crossing these for more than half a mile, they are again suddenly faulted against a mass of gypsum with some traces of an anticlinal structure, this being the gypsum of the central ridge and a continuation of the northern band of Kurár. The red clay zone makes no great show here on account of its softness, but is, as usual, present in inverted order overlying 250 feet of the nummulitic limestone, the back bone of the ridge, which likewise overlies, at angles of 65° and 70° to the south, a long series of steeply inclined or vertical beds belonging to the lower tertiary sandstone series. Another fault still cuts these off from the gypsum of the Zyaruttí ridge, on the northern side of which the limestone and lower tertiary sandstone lie in their proper order as shown in Fig. 53, a section through the Mittân pass, about three miles.

Cross-drainage.

The section.

Fault.

Fault.

Fault.

2. Gypsum 3. Red clay zone. 4. Nummulitic limestone. 5. Tertiary sandstone series, lower. 5a. Ditto, upper.

To the north of Shukkurdurra (Shakkardarrá) near the base of the central ridge which there becomes the southern side of the range, the continuation of the Báruk fault produces for some distance a very confused state of the rocks along a narrow zone. Here fragments of the series, chiefly of the limestone and gypsum, are wedged in a most complicated manner into tertiary sandstone series without relation or order, but when of any considerable size from their difference of texture showing themselves distinctly among the adjoining beds.

Continuation of Báruk fault.

On the ridge above the gypsum is extensively seen bent into large curves recognizable by flaggy layers, which near the top alternate with the red clays and have rough, ripple, or current marked surfaces. Above the red zone comes the limestone, often vertical, but sometimes showing well marked portions of the northern side of an anticlinal arch, or complicated slippage bringing it (out of place) over some of the adjacent beds. It here again contains the peculiar *Gryphæa*-like shell before mentioned, and several other nummulitic forms, none of which have been as yet examined for determination.

Current mark on gypsum.

Fossils in limestone.

From this the descent into the Wudda Brugdai valley is over the lower tertiary sandstones, &c., which in this rocky glen are much disturbed, sending faulted bands among the hills to the east and one compressed synclinal curve to the north-east. In the latter, down which drainage of the valley largely escapes, there are at no great height in the group apparently some greenish-gray soft sandstone layers containing the usual assemblage of fossil bones and exogenous wood.

Wudda Brugdai valley.

Bone bed.

The northern side of the valley is shut off from the Teeree (Tírí) gorges below Kureerosum (Kurírosum) by an extension of the Zyaruttí ridge, here forming the northern side of the range. On the inner slopes of the hills there is much gypsum seen, succeeded by the red zone and overlaid by nummulitic

North side of valley.

limestone distorted in places, but on the whole continuing the zyaruttí half anticlinal, the uppermost beds occurring on the northern side, except just south of the Saya (Séya) Malgheen salt quarries (Málgín), where both sides of the anticlinal curve are visible, the inner one coinciding with the northern side of the tertiary sandstone synclinal at the outfall of the valley.

Anticlinal.

From this place to the south-eastward the whole range from side to side is formed of ridges exhibiting complicated repetitions of all the groups from the tertiary sandstones downwards to the gypsum, below which even the salt itself appears as at two places, one near Peer Ghoot (Pír Ghút) Sír to the north, the other near the village of Kuroree (Kurorí) to the south.

Complicated repetitions of beds to east.

A general view of this ground may be obtained from the narrow limestone crag which forms the summit of Ghozheyreen Sír (so called upon the map, but in the native Pushtú gutturals sounding as nearly as could be imitated by the English letters Wgh-jeer-een-a, the first syllable forming a single sound) See Fig. 54 shewing the section across range from Zertungí to Shukkurdurra (Shakkardarra) plains.

Ghozheyreen Sír.

1. Rock-salt. 2. Gypsum. 3. Red zone. 4. Nummulitic limestone. 5. Tertiary sandstone, &c., lower. 5 a, Ditto middle. F. Faults.

From this peak, too, the whole of the harder rocks of the range may be seen cut off to the east by a north north-west south south-east fault, all the different groups running straight at and against an exposure of gypsum between two and three square miles in area. To the south-east also a patch of the nummulitic limestone, likewise faulted, is seen near Nundrukkí village, and the whole place appears to be another focus of faulting and disturbance, by the united agency of which the harder bands have been so placed that the range, instead of terminating as others do, is suddenly deflected nearly at right angles to the southward, accompanied by such contortion of the beds, in large compressed curves, that a length of outcrop equal to eight miles is

Great cross fault to east.

Change in direction of range.

forced to occupy a space between two points only four miles apart from north to south of the Húkaní mountains.

Nundrukkí gypsum area and salt.

In the wide area of gypsum just mentioned, and which is bounded by a thin disturbed band of nummulitic limestone and adjacent strata, the salt locality of Nundrukkí is situated, the guard tower marking the spot where the largest exposures occur. These are all situated in great crateriform hollows sunk among rolling gypsum-covered hills and receiving a considerable quantity of the local drainage by deep ravines, the streams disappearing subterraneously into dark caves in the salt to find an exit no person can tell where.

The salt is of the usual gray colour, and undulates with a northerly inclination; it shows cliff faces of 60 feet in depth, and, from different levels of the exposures, may have a thickness of more than 150 feet.

Recomposed gypsum.

The gypsum rises into rounded and many channelled hills intersected by deep ravines; much of it would appear to be recomposed on the surface containing a large admixture of reddish clay or earth, probably débris of the red zone, as well as fragments embedded of the nummulitic limestone enclosing fossils, and of the tertiary sandstones in a tender semi-crystalline base, sometimes containing small bipyramidal crystals of quartz and little crystalline fragments of dolomite. Some of it is black with or without the usual petroleum smell of these dark portions.

Red zone.

The red clay zone is best seen on the higher situations beneath the nummulitic band of Qund Húkaní (the widower's peak), but in lower places, where the gypsum rises above it, concealment often results both of this and, in places, of the limestone band. From the northern eminences on this rolling gypsum ground the contortions of the tertiary sandstone series in the Teeree Towey (Tírí Tauí) valley are very conspicuous, the dark purple and red lower

Contortion in Teeree Towey (Tírí Tauí) valley.

beds rising boldly over the axis of the Malgheen (Málgín) salt quarry ellipsoid, the synclinal hollow in which the Teeree (Tírí) river flows being filled with smaller anticlinal arches and synclinal curves, while so rocky is the ground, that each bed might almost be counted. At a short distance to the east, these smaller contortions disappear, and the beds sweep round the eastern end of the wide gypsum expansion, at the same time rising towards the rugged crest of the Húkaní hills.

Hokunní Mountain.

Between Nundrukkí boorj and the summit of Sookawar (Súkawur) Hokunní (3,170+70 feet=3,240 feet) a substratum of gypsum is covered by a broken crust of nummulitic limestone, in some places almost appearing to be *in situ*, as if large masses of the adjacent outcrop had here settled into a horizontal position. The very summit of the mountain is a narrow vertically bedded east and west crag, towering above everything else in its neighbourhood, seen from the north appearing as a hog-backed rise, but looking like a huge obelisk when viewed in the direction of its length. Around the crag, great fragments of limestone are piled, sometimes of the size of houses, and on its slippery apex there is barely room for three or four men to perch themselves. Looking from here, the compressed and very steeply inclined folds of the limestone are seen followed within by the red clay zone and projections of gypsum, and outside by the lower beds of the tertiary sandstone series, plunging down below the valley of a deep sandy bedded nullah tributary to the Teeree Towey (Tírí Tauí). Beyond this nullah the long horizontally stretching outcrops of the middle beds of the same group sweep round the opposite hills, slightly inclined from the spectator, all the upper part of these hills showing for a great thickness the peculiarly billowy, fretted, and mammillated surface, produced by the rapid disintegration of the soft glistening sands of the upper part of this great tertiary group, extending thence to the Indus above Mokud.

Sookawar Hokunní summit.

The surrounding country.

Towards the west.

In the opposite direction overlooking the Shukkurdurra (Shakardarrá) plain the outcrops of the tertiary beds are seen displayed as if drawn upon a map in bold open curves, which look all the more striking as minor undulations are lost sight of in the distance, the nearer beds showing converging southerly dips as far as the strongly marked mural escarpment of a great patch of these sandstones in the vicinity of Hussunshood (Hassanshúd) which shows a gentle inclination to the north from the slopes of the Lukkur Ghur mountains.

Limestone beds in gypsum outcrop of Hokunní.

Descending from Sookawar (Súkawar) Hokunní to Shukkurdurra (Shakardarrá) in crossing the outcrop of the gypsum, there were found associated with its upper part a 3-foot band of compact gray limestone overlying and indeed intercalated in gray, highly gypseous '*Sheenkoura*' shales with limestone layers. The whole group, including the thick gray shales and some gypsum bands below, has a thickness of 25 or 30 feet, exclusive of the main gypsum beneath, which is much concealed by débris.

These limestones were closely looked to for fossils, but nothing could be found except a fragment of an *oyster*, an imperfect cast of a small *bivalved shell*, and a few other shell fragments, all too indefinite to expect that they could be determined. The limestone, however, has much the character of some basal beds in the nummulitic series, and also resembles beds found occasionally in the gypseous portion of the Potwár Subáthu rocks.

These indications of themselves are all too small to build any argument upon, but taken together with other appearances, help to fix the idea that the gypsum at least, and possibly the salt as well, form part of an extended nummulitic succession.

Shukkurdurra plain.

The tertiary sandstones and clays of the Shukkurdurra (Shakkardarrá) plain have little to distinguish them from the great bulk of this gray and red series. They

certainly have not much the look of the lowest beds, and many of the sandstones are soft, yet the preponderance of alternations of reddish or red clay and light gray fragile sandstones prevailing westward, near Kurár mountain, is not marked here, owing perhaps to superficial concealment of all but the hardest of these soft sandstones.

Quicksands.

There is something in the incoherent nature of the sandy parts of the superficial covering, the local flatness of the ground, or the disposition of subsoil drainage that tends to produce quicksands (having doubtless an exaggerated character as to depth) along the margin of a sluggish stream which passes through the village of Shakkurdurra (Shakkardarrá). These are small circular patches in the damp ground where the hard rushy surface is suddenly converted into liquid sandy mud, perhaps kept moist by the presence of little springs. No stick could be found long enough to sound one of these, and their dangerous softness was said to vary at different seasons.

Newer tertiary beds south of Shukkardarra.

For four miles southward of Shukkurdurra (Shakkardarra) the harder strata project in the form of small hills, parts of contortions showing steep dips to the north and south. In this country, too, the hard crystalline pebbles from the newer beds of the series are strewed over the ground; these increase in quantity, ascending the bed of the stream which passes by Hussunshood (Hassanshúd), but it is not until close to this place that the soft gray sandstones are found to contain some small pebbly strings. Further south they increase in quantity on the surface to the exclusion of soil or anything else, thickly sheeting the ground and forming, as is their usual habit, smoothly dressed gentle slopes. Yet even here no strong bands of conglomerate are found from which they might have been derived.

Craggy hills near Hussunshood (Hassanshúd).

Within a mile south-westward of the above-named village, a rugged group of hills is reached at a place where 'perpendicular sandstones' is marked upon the map,

but this description only applies to their precipitous sides, the beds themselves being very thick, soft sandstones gently dipping to the north, or more nearly horizontal. In these beds there are again, but rarely, small conglomeratic layers with the same quartzite, syenite, and other crystalline pebbles as strew the neighbouring ground, of much smaller size and wholly insufficient to account for the quantity of the latter. Some dark gray shale bands also occur at wide intervals, and one peculiar orange layer of ferruginous clay is seen near the base of the cliffs. The sandstone is coarse, minutely specked with white atoms, micaceous and homogeneous, weathering into fantastic crags, one of which is perforated so as to look exactly like an artificial '*chhappar*' or shed. One peculiarity of these cliffs is that they show in places a steeply sloping talus, in which there would be nothing strange if it were

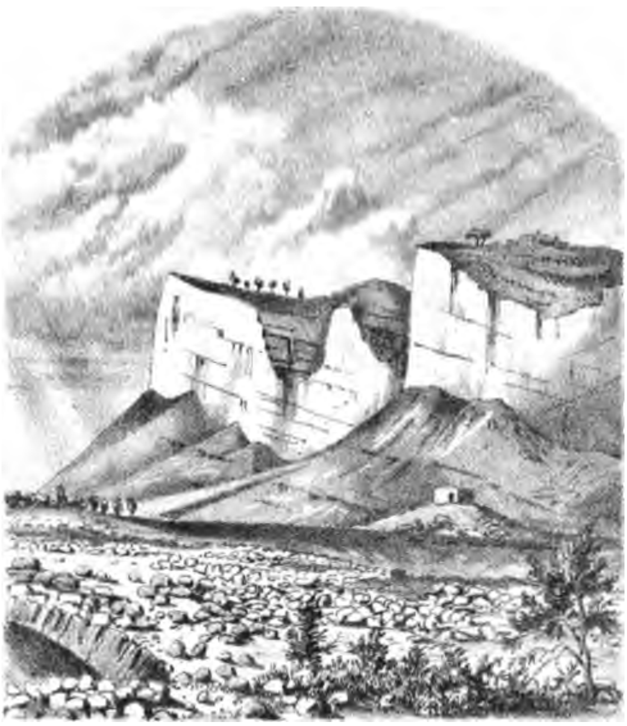


Fig. 55. Upper tertiary sandstone cliff near Hassanabád.

formed of débris, but it is instead a portion of the solid rock of the escarpment smoothly worn, and even at its junction with the vertical cliff simulating the arrangement of detrital materials, as seen in the figure (Fig. 55), of the upper tertiary sandstone cliff near Hussunshood (Hassanshúd).

The rocks are here so frequently seen, that any large stratum of conglomerate would probably show itself, so that the numbers of smooth, rounded, hard boulders and pebbles about may either be supposed to have come from one of the thick conglomerate zones of the northern side of the Sheen (Shín) Ghur range (as shown in Colonel J. T. Walker's section map No. 3, Northern Trans-Indus Frontier Survey) continued to the Lukkur Ghur, or to have remained the most indestructible parts of former conglomerates which had once existed over this ground.

ECONOMIC RESOURCES.

Salt.

The economic resources of this district are principally its enormous deposits of salt, which, being of great importance, are treated of under a separate section appended hereafter.

Gypsum.

Large as these salt deposits are, the quantity of gypsum in the district is probably still larger, even though appreciation of this be partly due to the greater display it makes over the district on the sides of, or within the hills. But the advantages to be derived from the use of this mineral in agriculture or the arts are apparently entirely unknown, and it is utterly neglected. In other countries it is mined for; here it could be obtained in any quantities at day-light. On the large expansion of the gypsum, &c., at Speena (Spína) the crops (particularly the wheat) are said to be better than in any other part of the country, yet the natives seem never to have drawn the inference that it would be useful as a manure.

Sulphur.

The sulphur pits at Gunjully hills, close on the northern limits of this district, have been already mentioned at page 99. From the way the alum shales have been burrowed into, much of the best part of the deposit may have been exhausted just at that spot, but there is no reason to suppose that it has not some extension beneath the neighbouring débris. It is on record (see foot-note to page 99) that 1,000 maunds of sulphur used annually to be won here, and it seems strange that the deposits are not now utilised as a source for the supply required at Láchee (Lachí) for the blasting powder manufactory where all the powder used in the salt quarries is made.

Alum.

There can be little doubt that the alum shale deposits mentioned in the foregoing pages would, if the manufacture was tried or encouraged, afford alum in the same way as those of the Chíchalí pass to the south.

Building materials.

There are several varieties of rocks in the country which would afford excellent building stone. Among these the nummulitic limestone would probably take the first place, and as there is considerable variety in the texture of its beds, it may be supposed that ordinary requirements would readily be met.

The harder bands of the gray and purplish slightly calcareous sandstone of the lower tertiary sandstone group are elsewhere very generally used as building stone, and would doubtless be found equally useful here. Mixed with the lighter coloured limestones they would produce a handsome variety of tints for ornamental 'ashlar' work, and among the most thinly stratified layers serviceable flagstones could probably be obtained.

Cement materials.

The limestones furnish lime, the gypsum would furnish plaster of Paris, the clay of various places is convertible by burning into 'soorki,' and there are occasionally to be met with in the Kohát district earthy limestone layers near the base of the nummulitic limestone which might furnish hydraulic cement.

Coal.

Since the previous pages were written, intimation has been received of coal having been found on the borders of, if not within, the district under notice.

By whom it was discovered is unknown, but its being brought to notice is due to a native officer of Kohát station and to Major MacLean of the Frontier Force.

It appears that the native officer when on leave heard of the existence of the coal near certain cliffs situated at some distance southward of the village of Dand, north-west of Shakkardarrá. He had great difficulty in finding anybody willing to show him the spot, and though, when he reached it, without any digging implements, he succeeded in extracting some baskets-full of the coal.

He could give no information as to the thickness of the seam, and could only say it occurred in a sandstone cliff.

The coal is described as bright, and to all appearance good, and the situation indicated for it is among the upper beds of the tertiary sandstone group, where thin layers of lignite and fossil-wood converted into coal are not unknown in other parts of the country.

At the time the examination of the district was in progress, places in the vicinity of the locality where the coal is said to have been found were visited, but of its existence nothing whatever was heard, probably for the same reasons, whatever they may have been, which made the people of the neighbourhood anxious to conceal it from the native officer.

From the position of this coal it seems unlikely to prove of much (if of any) economic importance. Coal or fossil-wood embedded in these tertiary sandstones is often bright and good enough, but totally deficient in quantity, yet there is no reason why a workable, though perhaps not extensive, coal bed should not exist among them.

Specimens of the coal are promised for transmission to Calcutta, and further enquiry will be made about the matter.

Since writing the former note further enquiry has been made, and Captain Cavagnari, Deputy Commissioner of Kohát, is of opinion that the Dánd or Dhand village alluded to is not the Dánd near Shukkardarrá, but the village of Shín Dhand in the country of the Jawakí Affrídís, a place not marked upon the map, but situated probably near the Jawaí (or Zhuwakaí) pass, crossing the eastern part of the Affrídí hills, projecting into British India between the Kohát and Peshawar districts.

It is not quite certain whether this may be the situation of another coaly bed; if coal exists there, it is probably a continuation of the carbonaceous alum shale zone which occurs on the north side of the Nilab Gash hills, near the village of Nummul, intersected by a stream which falls into the Indus from the right bank below 'Ghoratarap' (the horse's leap), where the stream is said to be only 60 yards wide. This alum shale is thought to be jurassic, or lower nummulitic.

A. B. W.

PART III.

EXTRACTS FROM REPORT,

On the economic aspect of the TRANS-INDUS SALT REGION, *by* DR. H. WARTH, *Inland Customs Department.*

With additions by A. B. WYNNE, *Geological Survey of India.*

Index to Part III. On the economic aspects of the TRANS-INDUS SALT REGION.

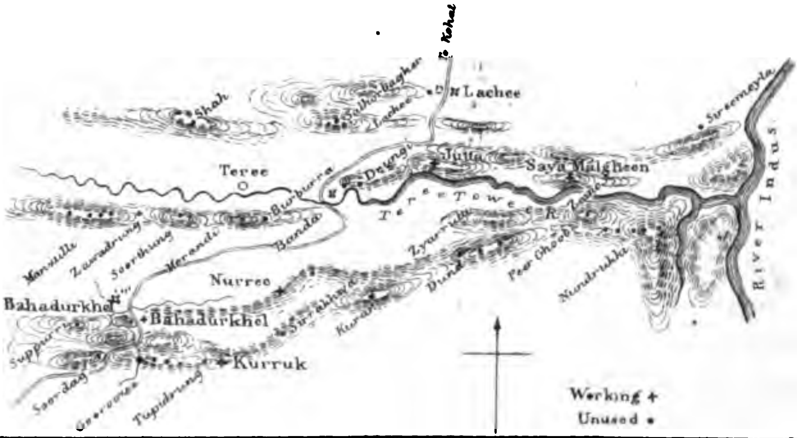
PART III.

On the ECONOMIC ASPECT *of the* TRANS-INDUS SALT REGION, *by* DR. H. WARTH, *Inland Customs Department, being extracts from the report submitted to Government*; with additions by* A. B. WYNNE, F.G.S.

The position of the salt region and the rocks found associated with the salt have been already described in foregoing parts of this memoir, and it has been mentioned that the salt quarried at Kálábágh, although situated on this side of the Indus, from its character and geological associations, is to be referred to the saline deposits of the Salt Range, rather than to those of the Kohát district.

There is a wide difference in the manner of working the salt of the Cis and Trans-Indus deposits, the former being all obtained by underground mining, while here mere quarrying is the rule, notwithstanding which, the name of 'Kohát salt mines' is often applied to the Trans-Indus salt quarries. For facility of reference the following sketch will show the relative positions of the old and modern salt quarries or localities in which the salt is now worked, as well as places where it is known to exist.

Fig. 56. Diagram shewing positions of salt localities.



* This report of Dr. Warth in full was forwarded to and printed by order of Government. Some additional historical particulars from Captain Plowden's memorandum are added here.

The quarries which are now open have been worked for a very long time: the Jatta quarries since 1650, and those at Malgheen (Málgín) from time immemorial, while those at Bahádur Khél are said to have been originated twelve centuries ago.

The following historical details are taken from Captain Plowden's memorandum (of 1872) already noticed:—

"Jatta is said to have been so called because it was first colonised by Jats, but it is now inhabited by Khattaks. When Khushal Khan, the warrior-poet, Khan of Teeree (Tírí), the bravest and most learned of his line, came to Teeree (Tírí) from Akora (about A. D. 1650), the salt was first quarried and sold for seven bulluck-loads per rupee to Bangashes and Affrídís, and twelve loads to Khattaks.

"Maglheen (Málgín) is so called from the Pushtú word malga, or salt; from time immemorial its quarries have been resorted to, but Sháh Báz Khan, Khan of Teeree (Tírí), A. D. 1780, was the first to make it a source of income. The Khans of Teeree (Tírí) and the villagers of Malgheen (Málgín), Dur Tappee (Dur Tappí), Dorshand, and Kureerosum (Kurírosum) have ancient proprietary rights therein.

"Nurree (or Narí) is said to be so called after one Narraí, who first settled here. He was succeeded by the Khojí Khél section of the land clan of Khattaks. They roofed their houses with branches of the Pullosa (Phúlahí?) tree (*Acacia modesta*); hence their village is also called Pullos (Punnose? on map). Its salt hills were first generally resorted to in the time of Sháh Zaman Sháh, Saddozai of Afgháníštán (Circa 1800 A. D.) The Khují Khéls are the proprietors of the soil and reside in the villages of Pullos, Tabbí, and Khurram.

"Kurruk, so called from the large amount of cultivated land (Pushtú karal, to cultivate) in the vicinity. It was first colonised in the time of the emperor Aurungzéb, but its salt hills were not quarried and resorted to by traders till about 1800 A. D. in the time of Sháh Zaman Sháh, Saddozaí of Afgháníštán. The lords of the soil are the villagers of Kurruk and Tappí, in shares of ⅔rd and ⅓rd, respectively.

"Bahádur Khél, the land of the Kurram clan of the Khattaks, now located north of the Teeree Towey (Tírí Tauí) extended from time immemorial to the present Wazírí frontier. Some twelve centuries ago, according to local tradition, one Daresh, whose mother was a native of Kurrum, came from Tank in the Derajāt to visit her. There were then four heads of families in the Kurrum clan. Daresh was admitted as a fifth and was awarded the waste lands on the immediate frontier. One Bahádur next came from Jordaud in the Kurruk (Khattak) country and settled with Daresh, who gave him half the lands. The Daresh Khél and Bahádur Khél, their descendants, are now lords of the soil within the limits of which the salt mines are situated, and divide equally among themselves the seigniorage allowed by Government. The Daresh Khél commenced trading in salt, it is asserted, immediately after their first settlement" (about 600 A. D.)

"The Khan of Teeree (Tírí) has an agent here to watch his interests as he enjoys 10 per cent. of the gross collections, and also to give assistance to the salt and the district police generally.

"The very low rate of duty now obtaining at this mine was originally fixed for a variety of reasons,—first, because it was difficult of military approach from Bánnú owing to the Soordág (Súrdág) pass which leads to it being a difficult one to force in case of resistance from its warlike Khattak inhabitants and their Wazírí neighbours. Its salt had, moreover, from time immemorial sold at a low rate because of the distance and difficult routes traversed by its frequenters (Wazírís, Ghilzaís, Turís, Mattaní and Kharjun sections, Khattaks of Durra, Upper Bangashes and Bannúchis), and came at length to be considered the perquisite of the Wazírís and other western tribes, for, notwithstanding its cheapness, the habitués of the neighbouring mine of Nurree (Narí) never resorted to it before our rule, nor do they now. For these reasons, and because his doing so would in no way affect the trade either for good or evil, Major Reynell Taylor fixed the low rate (now obtaining) at this mine. It would, he remarked, keep things as they had ever been,

and prevent, until a fort should be built at Bahádur Khél, a coalition, as in February 1850, of Wazírís and men of Bahádur Khél and Daresh Khél against Government. Again, the Bahádur Khéls were at that time and for some few years after in but nominal subjection to their chief, Khwaja Mohamed Khan, whilst their village held the approach to the mine." Captain Plowden notes. 'Captain Cokes' writing in March 1853, that this village was formerly noted throughout the whole district as the refuge of all thieves and murderers in the vicinity and the most *yagí* (lawless and independent) village in the country, not having for years paid any revenue, but he adds that the presence of a fort had made the people as well conducted as those of any part of the Kohát district, and converted them into regular revenue-payers. A carriage road' [? Gun Carriage] now 'runs through the Soordag (Súrdág) pass, and the Wazírís have imbibed a wholesome respect for a Government which has been stable and powerful for over twenty years, and have settled down into submissive subjects and peaceable neighbours, whilst a fort has been built at Bahádur Khél, and is held by detachments of Native Infantry and Cavalry."

Method of quarrying.—There are two methods applied in working the Trans-Indus quarries. At Jatta, Malgheen (Málgín), and Nurree (Narrí) gunpowder is used, and the salt is given to the merchants in irregularly shaped pieces, whilst at Kurruk and Bahádur Khél it is obtained in slabs, detached from the rock by pick-axe and wedge without the use of powder. These slabs are called 'tubbís' or chukkis,' generally the former.

The tools used by the miners or quarrymen are, a pick sledge called '*koowar*,' 12 to 20 seers in weight, a smaller pick, '*sooták*,' a crow or jumper, called 'jubber,' a needle for the blasting bore, '*sík*', a spoon to clear the borehole, '*kurrundi*,' and a hand barrow called '*bangai*.'

The method of cutting the salt by fresh water is not in practice anywhere in these quarries; possibly it might be adopted in some places, but would require engineering contrivance.

Vault-shaped quarries.—Where gunpowder is used, the quarries are usually worked in the shape of a vault, sloping downwards at an angle of about 60°. The vaulted shape of the cutting in the salt-rock and overlying bank of débris is to give some security against falling in, and the sloping position is chosen to give stability to the débris and waste salt which had been filled into the empty space, created by the preceding excavation. The quarrymen cannot afford to remove a large quantity of the overlying débris at a time, and thus lay bare a large surface of the rock-salt upon which to work, and having to work successively, they just take as much débris away as will enable them to go on with the salt excavation for the time being. When they have excavated deep enough to make the removal of the salt difficult, they start afresh from above, commencing by throwing the overlying débris down into the hollow which they have left. By the time this hollow is filled, a certain surface area of rock-salt is again laid bare, having the shape of a ring segment from 4 to 20 feet broad, extending round the margin of the former vault. The area being ready, the excavation of the rock-salt is again taken up. A cutting is first made along the new inner boundary by means of the pick-axe, and then blasting is commenced. A blast takes off about 20 or 25 maunds of salt, and as the blasting proceeds, the cutting is carried ahead along the inner wall so as to form a fresh vault gradually as the old vault disappears; the face of the débris which had been filled in is laid bare, but remains standing, owing to its sloping surface, down which the road leading to the bottom of the quarry is carried. Had the excavation been worked down vertically and the débris been thrown into the previously excavated space when the salt was removed by the new working, earth-falls would occur from the face of the débris.

To this type of quarry, the general features of all, more or less, approach. Where the 'heading' is more than average, we even find real mines on a small scale, though never without daylight, whilst with exceptionally little débris the quarries are more open with a larger working surface.

The excavation of salt without blasting powder.—At Kurruk and Bahádur Khél the rock-salt is excavated without the use of blasting powder, the preference given by the traders to the old form of slabs, (called *tubbís*)* got by pick and wedge, seems to have prevented the introduction of gunpowder at the above-mentioned quarries. The slabs are all of an equal weight, (1½ maund Síkh weight), thus saving the necessity to weigh the salt, mere counting being required, besides some check to prevent the tubbís from being made too large.

The tubbís are flat, square slabs of 13 inches breadth and 4 inches thickness, their formation being aided by the stratification of the salt. The men ingeniously arrange their working places so that all the slabs are broken off in the line or plane of stratification, the space worked upon being from 10 to 20 feet in length and of an equal breadth measured down the slope of the bedding.

The most convenient localities seem to be those where the stratification of the salt dips at an angle of 45°. The working surface being prepared, the men begin by making channels with their short-handled picks of hammer-like form, so as to cause the isolation of a number of squares over the surface, separated by channels 3 inches wide and 4 inches deep, the latter equal to the thickness of the slabs. The pick-axes have heads of 3 seers in weight and cut remarkably well, or else the salt must be comparatively soft. I certainly would not have expected such quick cutting if tried at one of the Cis-Indus mines. From the mode of working, the channels get narrower as they penetrate, whence the slabs have sloping or bevelled edges. It is at the pleasure of the workman to finish the channels over the surface and thus have all the slabs ready for breaking off, or else to get one slab after another ready for

* It is curious to observe the predilection that seems to have obtained from remote times for salt in the form of blocks having some prescribed form. Here it is cut into tubbís. At the salt mines of Abyssinia, we read that blocks of it pass for money, and that at Toudem in the Sahara it is carried from the mines in a form resembling tubbís also, while even at the Wieliczka mines in Poland, barrel-shaped blocks are prepared for transport. Lumps or blocks of salt are said to be preferred by the Afghan herdsmen, who take the salt from Bahádur Khél for their cattle to lick.—A. B. W.

separating. The breaking off is very easy: a small, round, pointed iron is used as a wedge and driven in at the base of the slab by the aid of one of the hard boulders to be found in many parts of the country; the slab breaks off after a few strokes. By advancing the upper rows of slabs more quickly, the men can obtain convenient steps for themselves to stand upon and to move up and down to and from the working places. A tubbí seldom breaks, and from long practice, their size and weight becomes very uniform. If there is no connivance with the merchants, it is not the workmen's interest to make the ' tubbís too large, for the larger the size, the more labour they cost.

In Captain Plowden's manuscript, the time required for excavation of the tubbís is given thus (from Mr. Carne)—An isolated tubbí is got out in 25 minutes, a second one alongside it in 17 minutes, by one man, but it is not said how many sides were cut in each case. It was said at the quarries that a man can get out 16 or 20 tubbís in a day, and from the method pursued, it follows that the labour of cutting out a single tubbí is twice as great as that required for cutting one among a lot.*

DESCRIPTION OF THE FIVE WORKING QUARRIES.

Jatta quarries supplying the depôt of Ismaíl Khél.—The quarries and salt outcrops of Jatta may be said to extend over a space half a mile long and a quarter of a mile broad. They belong to an inlier stretching east and west, enclosed on three sides by limestone ridges and opening on the fourth or eastern side to the valley of the Ismaíl Khél river which crosses the inlier. The highest hill is to the south. The distance of the Jatta quarries from the depôt at Ismaíl Khél to the north-west is three miles, and the road is extremely bad; that village, however, is only half a mile from the Bánnú and Kohát road, which, being a good one, is of

* In the Cis-Indus mines, a similar method, though not exactly the same, was in vogue before the introduction of blasting (shortly before or after 1860). Channels were cut into the face of the salt-rock so as to expose a rectangular block of several maunds in weight with one side adhering. Along this side two or three holes were made, into which were forced heavy pick-axes called '*hamras*,' which received heavy blows until the whole block broke off.

immense benefit to the traffic. It is to be regretted that a good road has not been made from this to the quarries.

At the time of my visit (January 1874) there were nine different quarries at work, and at six more places the salt was exposed; all the quarries were situated at the interior slopes of the enclosing ridges. The number of quarrymen was 100, and each had on an average 90 square feet of horizontal rock-salt surface to work upon. The amount of débris overlying the salt is in several places very great. It may be fairly said that the amount of salt excavated in each quarry is on an average not equal to twice the amount of débris which had to be removed. Six of the quarries at work were of the kind described as vault-shaped. There was one very large quarry measuring 150 feet along the floor, and exposing a salt wall of 50 feet in height, with from 20 to 50 feet of débris over it.

This wall was concave, almost semicircular, but only slightly overhanging, so that the débris was kept with difficulty from falling down. On a second visit after a fall of rain and snow, I found much water accumulated in this quarry which had to be baled out; the quarry is situated at the south-western side of the valley. The other five quarries of the same kind were of various dimensions, from 25 to 125 feet in length, and from 10 to 40 feet in depth. The three remaining quarries differed from the usual form.

The working surface of one consisted of a succession of steps along the base of a vertical salt wall 100 feet in length and 50 feet high. For half the length the quarry was temporarily closed by a great down-fall of débris from above.

A less significant place near it had a working surface of 20 feet by 10 feet.

The last quarry was of rectangular shape, forming a pit of 50 feet length, 30 feet breadth, and 15 feet depth in the salt. To expose this large surface of rock-salt a heap of débris 30 feet high had been removed.

A salt outcrop over one of the quarries shows the salt stratum to have at that point a thickness of 100 feet, but as the bottom of the salt has not been reached, its total thickness may be much greater. There is some stratification seen in the upper part of the salt, but below in the quarries, it is, as a rule, compact, without any trace of stratification, though this would probably be difficult to perceive from the purity of the salt and quantity of marks of the pick. At one place there are apparent interstratifications of soft sand and clay, but these were also found filling cracks extending to the surface from which they could be filled. The apparently anticlinal arrangement of the salt here would lead to the supposition that where the quarries are, it is nearly horizontal. This Jatta locality forms an exception to most of the others in the absence of springs.

Malgheen (Málgín).—The salt quarries here are situated in a range of hills at a distance of fully four miles southward from Málgín, and on the left side of the Teeree Towey (Tírí Tauí) river. The northern side of the range is occupied by an almost vertical ridge of limestone and sandstones; below the limestone comes red clay, and under this the gypsum and salt group stretches from east to west, with the river on the south. The total length of the ground over which the salt outcrops occur is three miles. At the eastern end opposite to the village of Zertungí are the old Zaino quarries, and at the western end above the village of Saya (Séya) are the quarries of Malgheen (Málgín) from which salt is raised, those of Zaino being closed.

These Malgheen (Málgín) salt quarries are more difficult as regards supply than those of the other depôts; the space they occupy is not more than half a mile long and a quarter of a mile broad, the average height above the bed of the river being from 300 to 400 feet. The number of old quarries is so great, that with difficulty places are to be found where, within reasonable depth, remaining patches of rock-salt can be dug out. The salt in these quarries, except near the top, showed little or no signs of stratification, but at an outcrop east of the working

quarries almost horizontal lines of stratification were observed, and a thick regular band of gypsum parallel to the salt rested upon it. From this and the general appearance, the salt about the quarries may be considered either horizontal or slightly inclined to the north. The amount of débris about the quarries is very great, and the whole ground seems already so worked over that no continuous supply of salt can be expected from any of the openings.

In January 1874 there were thirteen different places of excavation at work. Of these eight agreed in construction with the vault-shaped form of quarry which is specially adapted to a place where such a great mass of débris exists. Two of these vault-shaped quarries had just been started afresh from the top, the space within the former vault had just been filled with débris, and more of this was being removed to clear the necessary surface of rock-salt. The other vaulted quarries had working surfaces from 20 to 50 feet in length and from 4 to 10 feet in width. In one of the quarries earth and débris not only limited the salt wall on both sides, but appeared also behind, so that evidently the last remaining piece of salt within reach was being worked out. The wall leading to the salt through the surface débris was in a most dangerous state and ready to fall in.

The largest of the vault-shaped quarries measured 50 feet long at the base and 10 feet broad; it was connected with some caves, the remains of other excavations. A road led through these caves by which bullocks brought up the salt from the working; the salt wall *in situ* was about 60 feet high, whilst the heading reached at one side up to 100 feet above the bottom of the quarry. Notwithstanding the large exposure of the salt, no distinct stratification could be noticed, and large cracks were seen in it filled with clay or débris. A man had been killed here by the fall of an overhanging bank of the latter a few days before our visit.

Another of these vault-shaped excavations had all the appearance of a mine; it had been carried out at an angle of 45° into the hill side for

40 feet, and the detritus rose 40 feet also above its mouth. This was situated east of the excavations previously mentioned. Besides these and workings which followed the standard method, there were places worked in a different way, and exhibiting still more difficulty in obtaining the salt.

At one of these the men had found only two small pieces or veins of salt, one 6 and the other 12 feet thick; both were extensively enveloped in débris; they appeared at the bottom of a well 40 feet deep, which was liable at any time to fall in upon the workmen. At another place a single man was working in a most dangerous hollow at the base of which mere blocks of salt were embedded in the debris. Another excavation was worked so as to leave rather a convex wall of salt. This unusual shape was owing to the peculiar outline of the débris towering above.

Further at the bottom of a great crater-shaped hollow in the débris of at least 80 feet in depth there was a regular tunnel driven into the salt. It had two entrances, and was about 50 feet long and 10 feet by 10 feet wide. The men worked without lights, although it was almost perfectly dark in some parts of the tunnel. However their workings resemble real mines they evidently object to work with lights.

The most perfect mine was seen on the south slope of the hill towards the Teeree (Tīrī) river; its mouth was 10 by 20 feet, and it went for about 50 feet into the hill. Its height and width within were from 20 to 25 feet. There was very little salt to be seen, the débris appeared almost everywhere, and the place was dangerous enough, yet not more so than others.

How deep the still unworked portion of the salt extends here is a mere matter of speculation. I have no doubt it extends a good depth further than can be seen, and the bottom has not been reached in any of the workings.

Thus it appears that, under the present system, the thickness of the whole salt deposit is gradually diminishing through excavation of the

upper strata, whilst the mass of débris overlying the whole surface is becoming thicker and thicker at the same rate from the addition of waste salt. Instead of the overlying 'heading' being once for all removed to a distance, it is lifted and shifted over and over again in the course of many years.

That these Malgheen (Málgín) quarries are in difficulty as regards the salt supply is further evident from the small amount of working surface. An approximate estimation of this in each of the thirteen quarries or mines above enumerated gave a total working surface of 3,000 square feet only. The number of workmen was 100, so that each had only on an average 30 square feet to work upon, whilst at the Jatta quarries there were 90 square feet for each man.

The annual production of the Malgheen (Málgín) quarries is about the same as of those at Jatta, or in round numbers one lakh of Síkh maunds.

Nurree (Narí).—The Nurrí depôt is, like Kurruk, a second rate one, only intended as a kind of reserve for Jatta, where the necessary supply of salt could not well be obtained all the year round. During the time of our visit the trade at Nurree (Narí) was very slack.

The quarries are situated on the northern slope of the hills south of the village of the same name; the distance between the quarries and the depôt is only a mile.

The salt outcrops extend over a length of two miles, but in order to facilitate the guarding, the quarrying has been confined within a space of half a mile long and several hundred yards broad; there are several large crater-like hollows of more than 100 feet in depth, the sides of which exhibit the salt in many places. Here and there the men had cleared off the débris and begun blasting: most of the working spaces being 20 feet broad or less. There was very little salt accumulated, and very little recent work done. The few quarries were all open, the amount of débris not being considerable, and the salt surface was more than was required. The most troublesome part of the work was left to the merchants: they

had to bring their cattle over the most difficult pathways on and along the sides of the deep crater-like hollows to reach the quarries, whence they had to remove the salt and bring it down to the depôt at Nurree (Narí).

The whole thickness of the salt seam, as far as was actually visible, appeared to be about 200 feet, and over the whole of this thickness there was scarcely any salt seen that would not have been saleable, the salt here being generally considered of first-rate quality. The place lying high, there are no springs apparent in the salt.

Kurruk.—This, like Nurree, is only a salt depôt of minor importance, serving to supplement Bahádur Khél. As already stated, the salt is excavated in the form of slabs or '*tubbís*,' and débris has in some places to be removed in order to approach the salt, the inclination of the stratification, too, generally sloping into the face of the hills at angles up to 40° and 45° considerable excavation has to be made to expose places favourable for the tubbí system of working on the upper surfaces of the beds.

The outcrops are traceable for some hundreds of yards along the indented and eroded outcrop of the gypseous series. The mineral is more pure than the average at Bahádur Khél, and is said to be heavier; it contains numerous blotches of transparent salt *(shishi nimuk)*. The exposures vary from 20 to 40 feet in height, and some of the quarries are worked into the salt below the local level of the ground.

The extent of the quarry ground may be from one-quarter to one-half of a mile in length, and a few hundred yards in width, with a deep heading of gypseous and clay débris over nearly the whole of the ground. Springs of water occur in some of the workings situated at low levels, and large pits in the salt or open quarries had become half filled with clear saturated brine. The trade at the place did not seem very brisk, though apparently larger than at Nurree (Narí). The distance from the salt depôt at the village of Kurruk is less than a mile, most of the road lying over the sandy bed of a river which has to be crossed.

Bahádur Khél.—The quarries of Bahádur Khél are situated in the richest outcrops of the whole Trans-Indus region, these exceeding by far any of the outcrops in the Cis-Indus Salt Range. These outcrops extend over fully four miles in length, with a breadth of from a quarter to half a mile, between two ridges, running from east to west. In the eastern half of this tract the salt shows in a great number of outcropping exposures, while the western half is almost entirely of naked salt; patches of gypsum or earth to conceal it being rare. The road leads over salt, and the brook of saturated brine which drains the valley flows westerly over pure salt-rock, part of the salt surface being cut down by the water to the level of this stream. The salt which has retained its higher level forms embankments on either side of the valley, or rises in hills within it. Two of these are remarkable for their size, being about 200 feet high, and standing near each other in the middle of the basin (see Frontispiece). The strongest dip of the salt is to the north; but there are indications of an anticlinal structure. Where the salt is most exposed, it has a breadth of over 1,500 feet, with an angle of inclination that gives a thickness of at least a thousand feet, and as this only includes what is visible, the actual thickness there may be much greater.

The larger portion of the salt consists of pure workable strata, a small part only being unfit for excavation. I measured on the western of the two large salt hills mentioned a continuous series of workings through 140 feet of salt strata. Besides this there were many other workings in the same line of section, as well as in other parts of the valley, near where it is crossed by the Kohát and Bánnú road, this having apparently decided the choice of locality. The salt, considered unfit for working, was that mixed with a larger proportion of the same bluish clay which, more or less, pervades almost all the salt layers of this locality. The clay is quite harmless, and it is only the larger quantity of it occasionally locally present which hindered the excavation of certain of the strata where purer layers were to be found close at hand; no other ad-

mixture with the salt was noticed. The taste of the salt is everywhere the same, and no traces of foreign salts could be found.

The salt is obtained in the form of 'tubbís' previously described; the quarries have accordingly all to be chosen, so that the working surface is parallel to the plane of stratification.

The number of the quarries at work must be at least 30 (60 accordding to Mr. Carne: Captain Plowden's Memo.), and there are a great many more abandoned, most of which are filled with brine from springs which are said to be unusually numerous in this salt.

The number of quarrymen is said to be about the same as at Jatta and Malgheen (Málgín), namely 100, but there should be more to produce the same outturn, because the tubbí system requires more labour. than blasting, but, on the other hand, much labour is saved by the absence of débris, which is so troublesome at other localities.

The main road from Bánnú to Kohát (following a newer course than the one indicated upon the map) passes through the quarries, and by a capacious tunnel 500 feet in length issues from the valley, passing beneath the ridge which closes in the quarries to the north. Not far from the opening of the tunnel in that direction is the Mundí or depôt, with the Serai for the merchants and the salt establishment, about one mile from the quarries. Two miles further are the fort and town of Bahádur Khél.

17. *Excavation fees.*—The rates for excavation fees are as follows :—

At Jatta and Malgheen (Malgín)	about	1	Re. for	24	Síkh maunds,*	or $\frac{2}{3}$	anna per maund.
„ Narri	„	1	„	32	„	$\frac{1}{2}$	„
„ Kurruk and Bahádur Khél	„	1	„	16	„	1	„

A maund is equal to two tubbís.

* The Síkh maund is said to be equal to 1 maund 12 seers British. The British maund, for the convenience of non-residents of India, may be stated as equal to 80 lbs., and to contain 40 seers.

The salt is slightly dearer at the last two places on account of the method of extraction, and at Nurree (Narrí) it is cheaper than at any of the other quarries, owing to the readiness with which the salt can be extracted.

The trader has to pay for one maund of salt in the shape of tubbís one anna, in irregular pieces at Nurree (Narrí) half an anna, and at Jatta and Malgheen (Málgín) two-thirds of an anna; the average fee for the excavation of the salt is thus between half an anna and an anna per maund. This excavation fee is quite distinct from the price which Government takes for the salt.

Cost of the salt at the five working places, exclusive of the excavation fees.—This is fixed as follows :—

	R.	A.	P.
At Ismaîl Khél the price of one Síkh maund is	0	4	0
„ Malgheen (Malgín)	0	4	0
„ Nurree (Narrí)	0	4	0
„ Kurruk	0	3	0
„ Bahadur Khél	0	2	0

N. B.—Kábulí rupees are taken at the rate of 12½ annas to the rupee, 5 of the former being approximately equal to 4 British rupees.

At the two latter depôts only a few of the 'tubbís' are weighed to check their size, each, when properly cut, weighing 20 seers (Síkh), the rest are merely counted as so many half maunds. No sale of less than half a maund takes place, and where irregular pieces of salt are sold, each sale must be a multiple of 5 seers, or ⅛th maund.

Cost of transport of salt per maund.—The cost of transporting one maund of salt varies from one anna for eight miles to one anna for sixteen miles distance, according to the quality of the road. The excavation costing on an average less than one anna per maund, the expense of excavating one maund would be equivalent to the transport of the same weight over a distance of from six to eleven miles.

20. *Depôts.*—There are five depôts for the sale of the salt taken from quarries, not always in the immediate neighbourhood, thus—

1.	Ismaíl Khél,	supplied by the	Jatta	quarries.
2.	Malgheen (Malgín)	„ „	Saya (Séya)	„
3.	Nurree (Narrí)	„ „	Nurree, (Narrí)	„
4.	Kurruk	„ „	Kurruk	„
5.	Bahadur Khél	„ „	Bahadur Khél	„

Revenue.

Statement of the salt receipts and expenditure during the fifteen years, 1857 *to* 1872, *and during the one year* 1871-72.

	1857-72.	1871-72.
	Rs.	Rs.
Collection	12,48,961	78,027
Malkhana and contingencies	1,49,675	10,154
Cost of establishment	2,54,927	17,465
Nett profit	8,44,359	50,408

The average nett profit during the fifteen years was Rs. 56,290.

In the last financial year 1871-72, the net profit was below the general average, *i. e.,* Rs. 50,408 only.

Description of some old mines and outcrops.

1. *Sireemeyla* (Sírímela).—One mile from this village on the northern slopes of the hills between it and Weejosum (Wíjúsum) salt exposures were shown to us in two places near each other. One was purposely concealed by brushwood, the other was higher up near the escarpment of a gypsum hill, and from it I was able to break off a sample. The salt was of good quality; it appeared as if excavation had taken place here, but this was negatived by the native inhabitants of the place. Salt may be supposed to extend for half a mile here in the direction of the range, and with a width of 300 yards. The higher exposure is about 200 feet above the stream over the right bank of which it occurs, and the locality does not appear very favourably situated. The height above the valley not being great (and there appears to be a large mass of débris,) the dip of the salt could not be discovered.

2. *Lachee* (Láchí).—Close to the west of the village of Lachee (Láchí) on the Kohát and Bahádur Khél road, quarries in salt have been worked in former times, but have long been closed (from the statements of old people of the village probably about the year 1830 A. D.) From their occurring so near the road, these quarries are of some interest, and because they are nearer to Kohát than any of the others. They occur close to the foot of a limestone-covered hill, and over a rising ground covered by gypsum, hollows in which indicate the sites of the old quarries. In the valley of a small stream crossing this gypsum a weak brine spring issues. The hollows mentioned are very deep, yet no salt crops out in them. Concerning this locality the following information was collected:—

An old miner of Lachee (Láchí) village, stating his age at 71 years in January 1874, said, the salt quarries were worked in the life-time of his father, and that he also had cut salt in them.

The salt was sold at the Affreedee (Affrídí) pass to Pesháwur for Rs. 2 per maund, but was not carried across by the Láchí people to Peshâwur, they being afraid of the tribes in the pass.

The quarries were covered with a heading of clay, gypsum and débris higher than the two-storied bungalow of Lachee (Láchí) fort, even 30 guz (? cubits).

The quarry he worked in was about the size of a room in Lachee (Láchí) bungalow, and the salt was about as high as a man's stature all round. A spring filled the lower part of this quarry, but there was still salt below.

The water did not burst up in every place, and he thought it might be led to the river (that is, that it was higher than the stream to the south).

The salt was good in every way like that at Jatta.

The quarries were closed about forty years; they had been worked for forty years previously, and were abandoned on account of their depth and

the difficulty of managing the thick heading of débris.—From notes made as the man spoke.—A.B.W.

As the site of the quarries is scarcely 100 feet above the level of the plain to the south, the surface of the salt may be but little higher than the latter, and deeper excavation would require special precautions against the influx of water. Whatever form an excavation here might take either by quarrying or a low level tunnel, it is certain that salt could be obtained here if desirable. The quarries which may have been considered exhausted as far as the art of the local workmen was concerned would not be so with superior means at command.

The space underneath which salt may be presumed to occur is about 200 yards broad and 500 yards long. It need not, however, be confined to this area, but may continue westwards beneath the gypsum in a position better suited for mining.

3. *Sáthórbúgher, old mine or exposure.*—A mountain stream high upon the hills north of the Teeree (Tírí) valley works through red clay into a rib of gypsum, where it has an underground course for many yards, and being dry when visited, one was able to enter the mouth of the cave whence the stream issued. A salt surface of several yards was seen forming the left side of the cave chiefly, and traceable inwards as far as the mud allowed one to walk and as far as day light enabled it to be seen, *i. e.,* for 52 feet. The salt was of the usual character, dark in colour and part of it seemed to contain some gray clay. The place being high, a mine might probably be worked here, but the glen is very steep and narrow, and, as usual, approach over the belt of nummulitic limestone by the stream course is difficult and precipitous. The salt shows some lines of oblique lamination, dipping west at low angles.—A. B. W.

4. *Sháhdrung.*—On the west side of this mountain at the head of a long valley issuing at Murdan Khél a concealed salt outcrop occurs among red clay and fallen gypsum. The quarries here were open when Mr. Carne wrote, but inconsiderable.—A. B. W.

5. *Thríkanushpa.*—This is one of a group of old mines, and small exposures called by the general name Manzullí; it is a traditionary locality under fallen masses of gypsum; only some saline *shór* or efflorescence is seen.—A. B. W.

6. *Thór-drung.*—A little salt is seen here under a steep declivity, almost a cliff of gypsum, 150 to 200 feet in height, over which lies much débris of green or gray clay. There are two spots, at one only of which the salt is visible; it presents the usual characters.—A. B. W.

7. *Tapú-drung.*—A hill of salt apparently, capped by gypsum, &c. Green muds or shales dip at low angles west by south to pass under the hill, and a 25-foot cap of gypsum and clay covers it. The salt crops round the northern side of the hill, and the appearance is that of an isolated patch of salt in the clay and gypsum, but appearances cannot be trusted, as slippage or faulting might be present in such a highly disturbed place. This hardly resembles any other locality in the salt region except in a very general way on account of the appearance just mentioned. The thickness of the salt exposed may be from 15 to 20 feet, and the bedding seems to vary from horizontal to a slight southwesterly inclination.—A. B. W.

8. *Bádthór-drung.*—A little dark gray salt is seen just beneath the gypsum, as if between this gypsum and gray clays, the salt dips with the gypsum showing about 10-foot of an outcrop. There seems no certainty of any large mass of salt here; the relations are very obscure, and the whole place is open to suspicion of slippage. This is the last of the exposures to which the name of Manzullí was applied.—A. B. W.

9. *Záwá-drung* is a small exposure of salt in a nullah entering the right side of one of the heads of a stream which joins the Teeree Towey (Tírí Taui) at Sharki; the salt is covered by green clay, over which is apparently a large patch of gypsum, in which layers of gray clay occur irregularly.

10. *Soorthung.* (Súrthung).—On the northern side of this summit in a central ravine of the hills, are what appear to be old salt mines in

great vertical openings, showing an apparent thickness of 80 to 100 feet of salt under a 50 to 70-foot heading of shale or clay débris, with angular blocks of the local rocks; the salt is of a dark gray color, seems of good quality, and its stratification may undulate; some high dips to west and north-west were so indistinct that they could hardly be relied on. The gypsum, though seen near the place, does not now rest on the salt, and it is very possible that some of the gypseous clay called '*sheenkoura*' may have been the succeeding rock.

11. *Mírandí road.*—In a ravine where this pathway is about to leave the hills north of Totukki, amidst some gypseous and clay débris, there is a little salt, purposely concealed; it has a whitish-gray colour, and seems of good quality.

12. *Burburra, Serappah-drung.*—A deep khud here traverses much gypseous débris and red clay. In the main ravine and side nullahs huge masses of rock-salt are seen cropping from the banks for fully half a mile with an apparent horizontal arrangement and a thickness of perhaps over 200 feet. At one place there is an appearance as if a 50-foot band of the salt overlaid black gypsum; but as the latter might have slipped down, no weight could be attached to the observation; the salt is of good quality and of the usual gray colour. The whole place presents a most disturbed and shifted appearance, but as either a mining or quarrying locality, it can hardly be surpassed in this part of the district; it is also near the high road from Kohát to Bánnú.

13. *Bándá Surdág.*—In some of the small ravines about a mile east of Bándá seraí and rest-house on the road just mentioned, small masses of salt are seen in contact with purple gray clay, greenish and red clay, and lumpy masses of black impure gypsum, all jumbled together and affording no instructive section.

14. *Drungí Bándá.*—Eastward of the latter locality, and north of this *bándá* or village, are some reputed old salt mines in dark coloured (upper) salt which show in about 10 to 15 feet outcrops close to a

mountain stream, and beneath dark gray and black bituminous gypsum. The stratification seems to be at a low angle inclined to dip northerly; close by are rotten alum shales and some sulphurous springs.

The locality is one of much disturbance and complexity, and the low level at which the salt is seen is against it as a place for mining.

Zyaruttí.—Two small exposures of salt are said to be known beneath débris on the southern slopes of Zyaruttí hill.

15. *Zaino* or *Zino quarries.*—These occur at the eastern side of the ellipsoid hill, within which the Málgín quarries are worked, but no workings are carried on here. At this locality going from west to east are six large crateriform hollows, which all contain more or less salt. The depressions are at least 100 feet deep, and must be drained subterraneously by channels probably leading towards the Teeree (Tírí) river through salt gypsum and débris. The stratification of the salt appears nearly horizontal, as might be expected close to the axis of an anticlinal curve, and that it was once all overlaid by gypsum appears likely from the quantity of this rock lying about in broken fragments. In one of the hollows, a salt outcrop, 50 feet high, showed a regular stratum of gypsum, 10 feet thick, overlying the salt. The upper beds of the latter appeared very black, but when broken did not smell as might have been expected. Large masses of the salt were found which would be of inferior quality as regards consumption. At some places lower strata of better quality were seen; by keeping to these lower beds, salt of sufficiently good quality might be procured at any time. Beyond the crater-like hollows salt appeared also in a small transverse ravine, and beyond that another outcrop showed on the hill side. This last is very near the top of the ridge, at least 700 feet above the adjoining river valley; thus mining ought to have good prospects here. The extent of the Zaino exposures is half a mile in the direction of the ridge, but the breadth is small. Quarries are said to have been worked here in former times, but there are no traces of them now.

16. *Nundrukkí* lies north of Húkaní mountains and north-west from Shukkurdárra. North of the village of Nundrukkí there is a large area of gypsum, on a commanding point of which a guard tower has been erected; near this is a crater-like hollow with a subterranean escape. North and east of it are two more such hollows, with ravines running into them; these also have subterranean outlets. The sides of the craters are all naturally 'dressed' by earth and débris, amongst which large vertical cliffs of rock-salt crop out. It is of the usual appearance and gray colour. A good deal of heading would have to be removed before safe quarries could be opened, but for mining operations the locality seems well suited; the salt here must be nearly horizontal; there is a fourth hollow of the same kind to the east, but the salt is not seen. The craters being 200 feet in depth, this thickness at least may be attributed to the salt. Around this place there are some smaller exposures: one, called Súrdand-drung, lies within a mile north-eastward in the same gypsum area, another near it is called Esho or Yeshu-drung. Another occurs south-west from the watch tower near the village Kurrarí associated with a quantity of gypseous débris, and north-westward of the latter is still another small salt locality near the summit of Peer Goot (Pír Gút) Sír mountain.

17. *Dund, Durrí-drung* is the name of a small salt outcrop which occurs in the range connecting Nundrukkí and Kurár Sír and on its southern side, below gypsum. The locality is two miles east of the village of Dand, and is sometimes called by that name. The quantity of salt is very small, and the locality unfavorable for excavation, yet quarries are said to have been worked here in former times.

A small quantity of salt was said to have been once exposed between this and the Turrillí ravine or Mittân pass to the east.

18. *Kurár.*—A large exposure of salt occurs in the southern face of the hill below Kurár Sír, and a guard post has been built for its protection. The rock-salt has a thickness of 150 feet as far as it is shown by the outcrop, but this cannot be at all presumed upon as any limit of

its real thickness. One salt cliff near the guard-house is 60 feet high by itself. The salt is very pure; indeed, it is said that purer salt could be got here than at any of the other localities in the district. From what is seen the salt appears to contain only a minute proportion of the blue clay which forms the principal foreign ingredient of the salt at the western and other quarries. The uppermost strata only were here interlaminated with thin bands of black bituminous salt; some other layers contained small fragments of gypsum. The salt is stratified and shows a dip to the north; it is either colourless or of a light gray tint. Some that had a reddish look proved to be only superficially coloured by washings from a red marl above.

The salt outcrops for half a mile along the hill side, and projecting spurs from this are formed of the overlying gypsum from which the presence of more salt within the hill may be inferred. By removing the débris very large quarries could be formed and mining could also be advantageously carried on, as the salt rises 150 feet above the adjacent gorge.

19. *Speena* (Spína).—There are here on the north-western side and to the west of a large expansion of gypsum several large open outcrops of salt, some of which discharge brine in considerable quantities as shewn by the thick incrustations of salt in the stream below the hill and to the northward. The salt undulates slightly, and shows strongly round the sides of semicircular hollows. It is of the same character as usual, and much resembles the Nurree (Narrí) salt. The western exposures occur over the pathway in the pass of Kohneegá, on its north-eastern side, but at this place the rocks are all so much broken and disturbed that no relations can be discerned among the confused masses. The larger exposures would suit well for workings.

20. *Sirraíkhwá.*—Salt is seen in two principal places here, both in cliffs, north and north-by-west of the village of the same name, and, as usual, overlaid by gypsum and débris. At the most westerly locality the salt has a face 35 feet high and dips north at 40°. Nearer to the

guard-house or tápú there are large crateriform hollows evidently formed by solution of underlying salt, and a considerable hill shows a strong salt outcrop presented to the west, and dipping eastward beneath gypsum and tertiary sandstones. The salt in this hill may be 200 feet in thickness. The stratification is plain, and from the manner of exposure appears as if nearly horizontal. Oblique lamination lines in the salt occur, indicating currents coming from a northerly direction; its general colour is white or gray, and its purity intermediate between that of the Bahádur Khél and Nurree (Narrí) salts. The situation would be very favourable for any kind of working.

21. *Tápú-drung.*—Westward of the Kurruk group of quarries, there are several other outcrops, the place being known by the above name taken from a guard-house or boorj on the spot. The salt has the same general character as that at Kurruk; it dips to the north at 30° and 40°.—A. B. W.

22. *Gooroozí.*—There are numerous salt exposures from the village eastwards along a fault boundary between the gypseous series and tertiary sandstones; the salt is generally good, appearing in outcrops from 20 to more than 50 feet high, according to the appearance of the ground.—A. B. W.

23. *Záwá Álgud.*—Where this stream issues from a rocky gorge west-by-north from Gooroozí, great masses of salt are seen on the right bank and in adjacent nullahs: the exposure measured 560 paces across the strike, and the chief mass is about 80 feet in height; the salt is dark gray, like that at Bahádur Khél, but less laminated or more solid, and apparently more pure. A great deal of it was seen in perfectly naked exposures.

24. *Soordag* (*Surdág*) pass, or Thrukkah Álgud.—The salt here is near the southern mouth of the pass, and was traced along a faulted junction with the tertiary sandstones and red clays for 600 paces, being a few yards to a few feet in width; part of it is overlaid by gypsum

patches; the salt is nearly horizontally stratified, and the outcrops from 5 to 30 feet in height. This salt, dissolving under the atmosphere, covers itself with a layer of the clay which it contained; it is of the same character exactly as that at Baháдur Khél.—A. B. W.

25. *Sáppárri,* a salt locality in the hills south-west of Bahádur Khél, close to the British Frontier. The salt was not seen, only a strong saline efflorescence, and it was said to have been concealed by a fall of débris. The place is just at the watershed between the Changôsh and the Bahádur Khél streams.—A. B. W.

Besides the above there are a few smaller salt exposures near the others, sometimes called by separate names; thus Lukki and Kôtkullí between Sirraíkhwá and Kurruk, where a little salt is seen.

Total outcrop.—If the working quarries be included with the localities just mentioned, the exposures will number at least 335, exhibiting, when approximately although very roughly estimated, 3,082,996 superficial feet of rock-salt.

Total quantity of salt.—If the above exposures of salt be supposed to have a thickness of only 100 feet, the quantity present might be estimated at 500 millions of maunds, equal to the present demand for 1,000 years, but this estimate would be unreasonably low, for, in attempting to calculate the quantity, we must remember that the area of at least all neighbouring ground in which salt is probably concealed should be included, and then it would have to be reckoned, not by square feet, but by square miles. The Bahádur Khél, all but naked rock-salt, is four miles long and a quarter of a mile wide, giving one square mile of area: the Malgheen (Málgín), Jatta, Bárbárra, Gooroozí, and Narree (Narrí) quarries may be taken at a quarter to a fifth of a mile each, but these are only some among many localities, so that an area of five square miles may be fairly supposed to represent the space in which rock-salt is pretty certain to exist (though it may really be much greater). The salt strata measure 1,000 feet thick at one place at Bahádur Khél, but taking the thickness for the

whole of the above area as only 200 feet, this would give an amount of 40 milliards of maunds, sufficient, after making a large allowance for waste, to last at the present rate of consumption for over 40,000 years.

With such a vast supply there is little necessity to speculate, for practical purposes, about the existence of further salt treasures below the great gypsum area of these hills, but it would be satisfactory, in a scientific point of view, to know whether the salt is, or is not, as continuous as the gypsum under which it lies.*

Waste of the salt by rain and in quarrying.—The average rainfall registered at Kohát Station between 1863 and 1873 was 17·12 inches, and at Bánnú 11·25 inches, averaging 14·19 inches. If we suppose the latter amount of rain to fall annually upon the exposed salt surface, and a saturated brine to result, 0·2 feet of salt will be dissolved annually, but taking only 0·15 feet instead, as the brine would not be quite concentrated, the conclusion is arrived at that 4½ lakhs of cubic feet of salt are annually dissolved and carried off by rain water from exposed surfaces, an amount equal to 742,500 maunds of rock-salt!

Much salt must also be carried away by subterranean percolation of rain water, as may be seen in the incrustations of numerous brine springs, so that it will be within the limits of probability to say that the annual waste by natural agencies is equal to twice the amount sold. Compared with this great source of loss, the waste now taking place at the quarries by throwing away the small salt seems insignificant, being, perhaps, annually not more than one-sixth of the amount removed from outcropping salt by rain.

* This question applies both to the Cis-Indus and Trans-Indus salt regions. In both the gypsum extends through the hills, but the salt may be supposed with much probability to have a lenticular disposition. Here and there it reaches an enormous thickness, apparently over 1,000 feet in this region, and up to 600 feet in the other, but in other places it may have altogether disappeared.

The theoretical supposition of the salt having been deposited from the evaporation of sea water, separated entirely or temporarily from the ocean, and thus collected in the deeper pools or hollows, will be found mentioned above.

With regard to the waste of the salt in quarrying, it is true that even a larger loss is taking place at these than at the Cis-Indus workings. At the latter, chips of salt above half a seer in weight are all used, but here pieces of 5 seers are thrown away, and all the sharp corners of the blocks are rounded off, as well as the very great loss which takes place in the manufacture of tubbís. While in all cases economy should be practised in both localities, the natural resources are so great, that there is no actual necessity for causing inconvenience to the traders or outlay to Government in order to avoid wasting the salt. The waste from small salt cannot pass beyond certain limits, and much more damage might be done by irregular mining and by careless quarrying. If the beds of good salt within reach are systematically consumed by either mining or quarrying without allowing whole strata to become practically useless from the accumulation of débris, or to be destroyed by access of water, &c., the damage done by rejection of small salt can well be put up with.

The traders to the Trans-Indus depôts use only open palm-leaf rope net-works (turringries) for carrying the salt in; by introducing the use of bags as at the Cis-Indus mines, the waste of salt might be at least reduced to the lower standard of the latter mines, but even this may be thought the less necessary, because the amount of salt cropping to the surface is so much greater Trans-Indus.

Although so much in excess as to make it seem wonderful how these Trans-Indus outcrops have withstood destruction during a whole geological age, they must in coming centuries melt down to the level of the water-courses, or become deeply covered with débris through the mere action of the atmosphere, the excavation and waste being at the same time continued or not, locally, as the case may be. Mining, instead of quarrying, would then have to be carried on, and it would then be time to think of economising the small salt.

Foreign salts.—No deposits of potassa or other foreign salts have been found overlying any of the salt beds of this region, yet this is no reason why they should not be supposed to exist. I have, however, carefully

searched at all the outcrops which I examined, but have never been rewarded by finding any, not even a trace of their occurrence, though a small deposit of the kind has been met with in the Cis-Indus Mayo Mines.

The salt is constantly accompanied by gypsum, yet only at a few places (as at Kurrár) small fragments of this mineral have been found enclosed in the salt itself, and it required analysis to detect the presence of this mineral. Neither has anhydrite been found associated with the salt except as very small crystals in the gypsum of Málgín. The principal impurity of the salt in this district is a bluish clay, which is, however, rarely present in sufficient quantity to prevent its being worked. The uppermost salt layers include, at most places, black laminæ containing bituminous matter and smelling of petroleum; and sometimes the ordinary salt when of a slightly darkish colour, as, for instance, at Jatta, has the same smell when freshly broken, though but slightly. In one quarry here a layer of black earthy salt occurring in the midst of good salt was highly bituminous and smelt strongly of petroleum; it contained also pieces of iron pyrites and calcareous marl. On dissolving some of the upper bituminous salt of this Jatta locality, a residuum was obtained of a brown bituminous sand which burned white before the blowpipe, yet retained a slight petroleum smell. There was evidently not sufficient oil in the salt to appear as such on the water in which it was dissolved.*

* In Karsten's large work on salt (previously referred to, p. 37, &c.,) such reference is made to the occurrence of mineral oil with rock-salt as would appear to show that he was certain of some relation existing between the two. Thus at page 491, speaking of modern Italy, he says, "the occurrence of earth-oil in several parts of the country combined with its geological constitution to lead to the expectation of finding brine springs and even rock-salt, though neither were yet known." Again, at pages 506-7, he gives the result of borings for rock-salt at Marmarosh in Hungary. "The rock-salt is covered by 31 feet 8 inches of clay of various quality, 3 feet of which immediately overlying the salt has a strong bituminous smell, this bituminous clay being always the immediate covering of the salt." Another boring gave 31 feet 7 inches of strata overlying the salt, the layer of bituminous clay next to it being 5 feet thick, and the lowest 2 feet of the clay being saline (p. 587). He also says that all over the region of earth-oil and naphtha at Baku, &c., on the Caspian Sea there are also brine or salt springs.

At the Saya Malgheen (Séya, Málgín) quarries the upper layers of the salt alternated with black bituminous gypseous rock at one place, which contained small but beautiful crystals of anhydrite in transparent, colourless, rectangular prisms.

Geographical area of consumption of Trans-Indus salt.

Eastwards of this salt region the river Indus Customs line forms a great boundary confining the consumption of the cheap Koháмеt salt in that direction and separating its distribution from that of the Salt Range which pays a tax of Rs. 3-1 per maund. Kábul gets its salt from Bahádur Khél by the most direct route through the Koorum valley, which is reached in a few marches from Bahádur Khél by various rugged routes. Most of these lead over the (Manzullí) range of hills north of that place, then turning westward until the Koorum river is reached; from this part the traders follow the stream north-westward, others proceed westward and south-westward through the Wazírí country, the carriers being themselves Wazírís and Ghilzaís.

The most western limit said to be reached by this salt is lake Alistád* in the Ghilzaí country, south of Ghazní, at a distance of nearly 200 miles from Bahádur Khél. I learned, however, from a native of this Alistád region that this salt was carried further still in a westerly direction and down to Kándahar. At this distance, however, it was very dear, and equal in price to ghee, wherefore many people could not afford salt, and some used an impure efflorescence instead. He also said the Alistád lake was not a salt lake.

Another portion of the Bahádur Khél salt is carried southward *viâ* Bánnú into the Deráját, or country between the British frontier in that direction and the river Indus preventive line. For this route, too, the Kurruk salt is chiefly reserved, going by a more direct road past Sheik Búdín mountain to the south, but some of it is also allowed to go to Bánnú, and thence to the west along with the Bahádur Khél salt.

* Captain Plowden's memorandum. The name of this lake in the recently issued map of Turkistan is spelled Ab-istada.

The rate charged by Government at Kurruk being 1 anna, and at Bahádur Khél 2 annas, less than at the eastern quarries, salt from the west is forbidden to be carried in the direction of the eastern sources, a prohibition which ought not to be difficult to maintain, as the distance from Bahádur Khél to the nearest open quarry eastwards, that of Nurree (Narrí), is sufficient to counterbalance the difference in the rate by the increased cost of transport.

The two western sources supplying the countries to the west, south-west, and north-west, the three eastern localities are reserved for the countries to the north, north-east, and north-west. The Jatta salt is taken northwards along the Bánnú and Kohát road. The salt from Nurrí takes the same road. Camelmen, as a rule, are supposed to go to Nurrí for their salt, the road being better, while bullock-and donkey-men go to Jatta on account of the three miles of bad road between the quarries and the depôt being more accessible to their beasts of burden.

The salt having reached Kohát and supplied its wants, is taken on by the Affrídí pass to Pesháwur, a road for the use of which Government pays a 'black mail' of Rs. 12,000 annually to the Affrídí tribe, whose country stretches like a peninsula of hills into the British territory. Of the surplus remaining after supplying Pesháwur, a part is taken west by the Khyber pass, as far as Ningráhár, not generally reaching Kábul, but being consumed in the provinces lying on the way thither. Another part of this salt from Pesháwur is carried northwards to Bajour, Swát, &c.

Malgheen (Málgín) possesses a salt road of its own, called the old "Drung-ka-rásta," which, avoiding the Affrídí pass and country, leads up the right side of the Indus, crossing the Mírkálán pass into the lower part of the Pesháwur valley.

From the north of the last named pass, some of the salt goes to Pesháwur, but the larger quantity to the north-east, Yusufzaí, Bonér, &c., also across the Indus near Torbeyla, beyond the preventive line, to places whence no competition with the high taxed salt of the Salt Range could take place.

This road from Malgheen (Málgín) is a mere track, but is important, as all the northern salt trade would have to traverse it in case of the Affrídís closing their pass.

The distance from Bahádur Khél to Kábul being 150 miles, to Lake Alistád, 180 miles, and to the Híndú Kúsh, 200 miles, the consumption area of the Kohát salt region may be said to be included within a radius of 200 miles, this limit being probably not reached in all directions, notably to the east, where the circle would be nearly intersected by the preventive line, while it is exceeded in the Dérájat and Sind direction. Reports say the salt goes as far as Kándahar and Balk, which would be much more than 200 miles, but it is doubtful if any considerable amount of the salt reaches these distant places. The whole area through which this salt is distributed may be equal to 60,000 square miles.*

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* None of the salt of this country, nor any of that from the Salt Range, appears to reach the Yarkand territory, though some of the latter occasionally penetrates as far as Ladak, but not beyond.

This statement is made on the reply to a question contained in one of the last letters written by the late Dr. F. Stoliczka, under date Kufélong, June 12th, 1874, from which the following is extracted:—

"Pure salt in small cubic crystals sells in the Yarkand and Kashgar bazaars at the rate of 1 pice per pound, and common salt (efflorescence salt for beasts) at the rate of 7 annas for a donkey-load, somewhat over two maunds."

The lowness of these prices would seem to be sufficient reason for the Salt Range salt not being carried further than Léh, but even the much cheaper Trans-Indus salt, though it supplies the Yusufzaí country and hills north of the Peshâwur valley, does not appear to be worth carrying into Kashgar through the Jálálábad pass, said to be practicable for laden camels the whole way.—A. B. W.